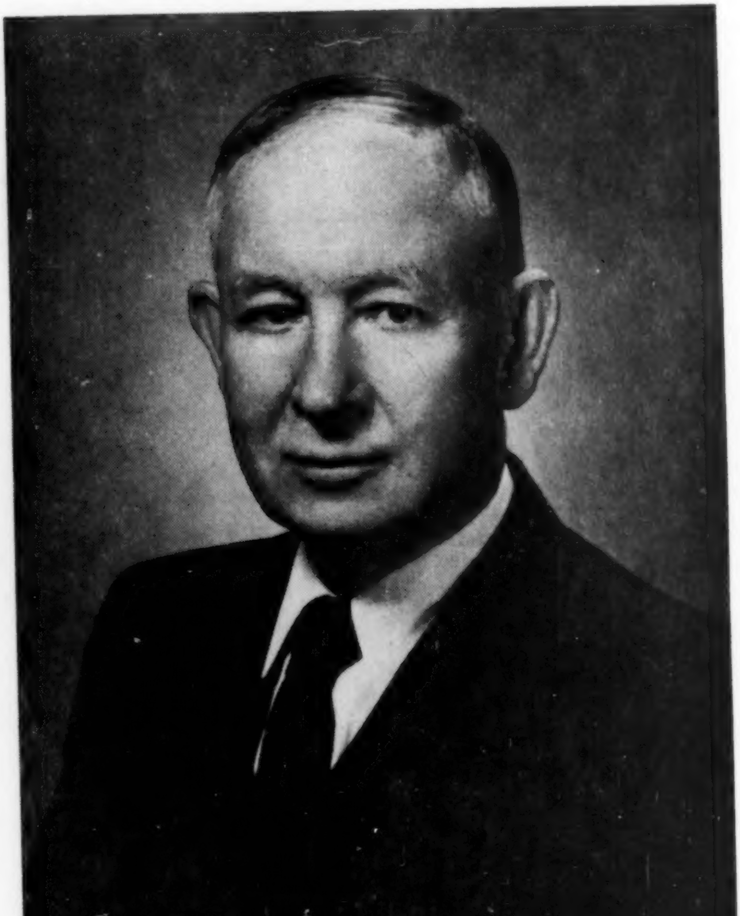
SCIENCE EDUCATION



Samuel Ralph Powers

VOLUME 40 DECEMBER, 1956 NUMBER 5

SCIENCE EDUCATION

THE OFFICIAL ORGAN OF

The National Association for Research in Science Teaching
The National Council on Elementary Science
Association on the Education of Teachers in Science

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NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Program

At the Eighth Joint Conference of the Science Teaching Societies Affiliated with the American Association for the Advancement of Science
December 27, 1956

9:00 A.M. East Room, Hotel McAlpin. *Symposium: Recent Research in Science Education.* Arranged by NATHAN S. WASHTON, Queens College, New York City.

NATHAN S. WASHTON, *Presiding*

1. "Survey of Research in Elementary School Science Education." GEORGE G. MALLINSON, Western Michigan College, Kalamazoo.

2. "Implications of Research in Elementary School Science Education." HARRY MILGROM, New York City Board of Education.

3. "Survey of Research in Secondary School Science Education." WILLIAM S. REINER, Board of Education, Bureau of Educational Research, New York City.

4. "Implications of Research in Secondary School Science Education." JEROME METZNER, Bronx High School of Science, New York City.

5. "Survey of Research in College Level General Education Science." EDWARD K. WEAVER, Atlanta University, Georgia.

6. "Implications of Research in College Level General Education Science." ABRAHAM RASKIN, Hunter College, New York City.

Continued from Inside Front Cover

SCIENCE EDUCATION

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FOURTH ANNUAL REVIEW OF RESEARCH IN SCIENCE TEACHING

Clarence H. Boeck
Associate Professor of Education, University of Minnesota
Chairman, Fourth Annual Review Committee

Jacqueline Buck Mallinson
Kalamazoo, Michigan, Vice-Chairman, Fourth Annual Review Committee

Clark Hubler
Professor of Science Education, Wheelock College
Chairman, Elementary School Level

William B. Reiner
New York City Board of Education
Chairman, Secondary School Level

Edward K. Weaver
Professor of Science Education, Atlanta University
Chairman, College Level

The Fourth Annual Review of Research in Science Teaching presents the work of thirty-seven NARST members who served on the three level committees. Their work involved the examination of over forty periodicals in search of pertinent research studies published during the period of August 1954 to August 1955. In addition, the report of unpublished studies in science education was made available to the committees by the United States Office of Education well in advance of its publication in *Science Education.*[1]

Every effort was made to locate all pertinent materials and to evaluate both published and unpublished studies in terms of the definitions of research previously used as criteria to be met in order that an investigation be included in the review.[2] It is characteristic of cooperative ventures that the application of basic criteria cannot be as consistent as might be deemed desirable. Differences of opinion as to whether or not to include studies were in evidence as the materials were made available for editing. Some omissions were made because the studies were previously reported as unpublished investigations in earlier reviews.[3] In other instances, omission of a study may have been the result of having an inadequate report from which to make judgment. This was as equally true of the reports of unpublished studies supplied to the United States Office of Education as it was of the articles submitted to the editors of periodicals.

It is the hope of the Committee that the Fourth Review, which it is pleased to present, will prove to be of value to science educators concerned with any and all phases of this important facet of the educational scene.

[1] Blackwood, Paul E. "Science Education Research Studies—1954," *Science Education*, 39 (December, 1955) 372–389.

[2] "What Constitutes a Research Investigation in Science Education," *Science Education*, 37, (February, 1953) 53–54.

[3] See *Science Education*, 38, (February, 1954) 55–101; 38, (December, 1954) 333–365; 39, (December, 1955) 335–371.

Review of Recent Research in the Teaching of Science at the Elementary School. Level I

Clark Hubler, *Chairman*

Charles K. Arey, Paul E. Blackwood, Glenn Blough, Stanley Brown, William C. Forbes, Katherine E. Hill, Oreon Keeslar, Grace C. Maddux, John G. Read, Robert K. Wickware

Studies Concerned with Teacher Training

During the past year the most frequently reported research efforts were concerned with studies of teacher training either in colleges or through in-service programs.

By means of questionnaires, Chamberlain [3] sought to determine the status of teacher training in elementary science. Four different questionnaires were prepared. Two were sent to colleges, one to members of the National Association for Research in Science Teaching, and one to qualified teachers of elementary school science. The teachers surveyed reported difficulty in obtaining equipment and books and in finding storage space. The authorities surveyed agreed there should be increasing use of simple materials and community resources. In the pre-service training programs, a lack of qualified faculty was reported; also reported was disagreement or lack of sympathy between education and science departments, overcrowded curricula, lack of interest or background in science on the part of students, and inadequate facilities for teaching. Similar difficulties were reported for the in-service program. Of 765 accredited colleges which train elementary teachers, 442 listed courses in elementary science in their catalogues. The median number of semester hours was three for such courses, and approximately nine hours of science background were required, though 523 of the colleges did not specify what type of courses was required. It was concluded that the trend is toward inclusion of more academic science and also more professionalized science in training elementary school teachers. It was noted, however, that due to the anticipated shortage of science teachers, secondary schools may strip the elementary of trained personnel.

Gega [4] sought to determine the relationship between reported problems in teaching science in the elementary school and elementary school science courses in California teacher training institutions. A list of problems was compiled from a study of the literature and data secured from 52 supervisors. Information on the courses taught in the colleges was obtained through interviews with the teachers of these courses. He found the most frequently reported teaching problems were, in order of magnitude: (1) materials and resources, (2) teacher skills, techniques, and security, (3) organization of instruction, (4) human relations, administration, and supervision, (5) objectives and evaluation. The teacher training institutions showed considerable differences in their offerings, requirements and approaches used in the teaching of the elementary science course. A single course offering was most common and more institutions did not require an elementary science course than did require such a course. Of twenty courses, nine offered an integrated content and method approach; seven emphasized method, and four were organized for content mastery.

Some attention was given to the preparation of specific materials for science courses to be taught to prospective elementary school teachers.

Weaver [11] developed laboratory experiences which were considered suitable for an integrated course in physical science for prospective elementary school teachers. A list of 43 criteria was developed for se-

lection of laboratory experiences and evaluated by a jury of physical science teachers in teachers colleges throughout the nation. Six of the criteria were rated as essential, and 36 as desirable. Fifty-five experiences were selected, developed, and revised by the investigator to meet the six essential criteria, and as many of the desirable criteria as possible were met for each experience. These experiences were then evaluated by another jury. In the judgment of the investigator the fifty-five experiences presented in the study included more than enough highly desirable experiences for a course offering a two-hour laboratory period per week for thirty-six weeks.

Science Education workshops were studied in two research studies.

At the University of Southern California, Bingham [2] questioned teachers regarding the kind of workshop in elementary science they considered valuable. The teachers expressed a desire for working space and a wealth of laboratory and library facilities, an atmosphere which promotes a free exchange of ideas, opportunity to plan much of the work, a chance to develop materials for their own classrooms, and wide provision for experiments. They prefer a sufficiently structured organization to guide the inexperienced person, and sufficient time to carry out the activities undertaken.

In their evaluation of a health-education workshop at Pennsylvania State College, Shaw and Coccari [9] concluded there is little relationship between a student's knowledge in health education and the rating of his contribution to a workshop situation, as measured by staff and fellow workshop members. The evaluations of the instructor and the students do agree regarding the contributions of individuals, however, and the study recommended that more emphasis be placed on such evaluations in determining final grades.

STUDIES OF SCIENCE INTERESTS

Morton [6] sought to determine the science interests of intermediate grade children in the Salt Lake City public schools. He used four techniques to determine interests: (1) topic selection in textbooks, (2) selection of science pamphlets, (3) personal interview, (4) check-list questionnaire. The results from the use of these techniques were not in agreement as to relative rank of the interest areas. Strong interests were found for topics in astronomy, earth features and magnetism and electricity. Little interest was found for machines and how they work.

Smith [10] found that first grade children were most interested in units concerned with weather, animals, air, aviation, and seeds. These findings were based on careful observation of the pupils during daily planning sessions, reading, and field trip experiences related to scientific principles.

STUDIES RELATED TO TEXT-MATERIALS

Beeler [1] tested the hypothesis that several aspects of the use of analogy in science writings for children have changed during the years, and that these changes parallel changes in educational procedures. Four chronological periods were established based on discernible changes suggested in the teacher training institutions for elementary school science. The periods encompassed the time from 1800 to 1952. Fifty textbooks and trade books were selected for analysis. The 6,829,000 words of text which were read produced 8,162 analogies, or an average of one analogy for each 835 words and 41 analogies per book. About two thirds of the analogies read were judged to have referents which could be experienced by children, either universally or commonly. Infrequent analogies made up about 5 per cent of the total. The incidence of analogy was erratic. The original hypothesis was declared unsupported.

Nieri [7] reviewed basic word studies to determine their fundamental similarities and differences. Examination of first-grade readers showed the types of stories and the variety and quality of subject matter used. It was found that first-grade children must be given content matter which challenged

their curiosity and thinking ability. The conclusion reached was that children at this level could follow a sequential word list based on science facts as well as on stories based on fancy. Text materials and a teacher's manual were produced based on these findings.

MISCELLANEOUS STUDIES

Lambert [5] and Pooler [8] worked individually at determination of the grade placement, 4th or 6th grade, of a particular physical principle. Their procedure was to use lecture-demonstration instruction to illustrate the principle to pre-tested groups at each grade level. After instruction to part of each grade-group, retesting was carried out. The work failed to produce definite conclusions. Although the study was with but a single principle by each worker, the method employed may well merit further consideration.

The status of conservation education in selected elementary schools and State Teachers Colleges in Minnesota was studied by Wedul [12]. Questionnaires were sent to 475 teachers in 9 counties, and all county superintendents were interviewed. Ninety-six per cent of the teachers had more than one year teaching experience; 14 per cent had no training for conservation education; 72 per cent had received all or part of their formal education in Minnesota Teachers Colleges; integration of science and social science was the most common practice in teaching conservation; less than 50 per cent of the teachers utilized audio-visual aids and indoor conservation projects; and about one-third used resource personnel. Four of the five Teachers Colleges offered separate courses in conservation education.

SUMMARY

Looking beyond the studies reviewed in this report, it seems that some new approach to children's interests and subject matter or the development of concepts is needed if further studies are to be rewarding. One suggestion might be to determine the reactions of children at various age or grade levels to subject matter or experiences of a given kind and degree of complexity. Likewise, the organization of content may be more significant than the question of what science principles should be included in courses for prospective teachers, and the reactions of students may be fully as important as the opinions of experts in determining what should be taught. Studies regarding the present status of science in elementary schools and of teacher training in this field seem to be in substantial agreement. Now the time seems ripe for more emphasis on ways of improving the present situation.

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Review of Recent Research in the Teaching of Science at the Secondary School. Level II

William B. Reiner, *Chairman*

Jerome Metzner, *Vice-Chairman*

Sam Blanc, Loren T. Caldwell, George T. Davis, Paul DeH. Hurd, Margaret J. McKibben, Greta Oppe, Archie M. MacLean, Samuel Schenberg, Harold S. Spielman, George C. Wood

Studies Relating to the Characteristics of Students

Anderson and Smith [4] investigated the influence of inheritance on pupil achievement in science and other academic areas. The achievement of twins was compared with that of siblings, cousins, and matched non-related pairs of individuals. Study 1 employed data from a state-wide study of graduating seniors. This study included seven sets of twins. No attempt was made to classify the twins as fraternal or identical. Each member of the twin pair was matched as closely as possible on the basis of intelligence test results with another member of the same class. Test data was available for students on the *Terman-McNemar Test of Mental Ability,* on all four sub-tests of the *Essential High School Content Battery,* and on the *Nelson Inventory of General Industrial Arts Background.* The analysis of variance technique was employed in analyzing the data, and the L-test was employed to test the assumption of homogeneity of variances. This assumption was found to be warranted in all instances.

Study 2 employed data from a study by Anderson, Montgomery, Smith, and Anderson [3]. Data were available on nine pairs of twins, twenty-one pairs of siblings, and nine pairs of cousins. Data included scores on the *Terman-McNemar Test of Mental Ability* and the *Nelson Biology Test.* A statistical analysis was made of the data, employing the same procedures as in Study 1.

The conclusions reached:

(1) Performances on science and social science sub-test were not independent of membership in the twin pair. The sections of the test on mathematics and English failed to yield significant results.

(2) Twins showed higher intra-class correlations in intelligence test scores and biology achievement tests than either siblings or cousins. Siblings showed lower, but still significant intra-class correlations in both intelligence test scores and biology achievement test scores. No significant relationships were found in the performance of cousins.

(3) A decline in common genetic factors is accompanied by a decline in the relationship of the performance of assorted pairs. Heredity is still a major factor of influence on the achievement of students in subject matter learning.

Bull [6] made up case histories of 100 high school pupils having dominant science interests and hobbies who were recommended by their science teachers. It was the purpose of this study to analyze the background and activities of these persons in order to determine the conditioning experiences which seemed instrumental in developing science interests. He found (1) Most pupils having dominant science interests and hobbies developed these interests at an early age. (2) The large majority of pupils with dominant science interests and hobbies are superior in

scholastic ability to the normal pupil in the same schools. (3) Three-fourths of the pupils with dominant science interests and hobbies have a preference for interests and hobbies involving physical science. (4) Nearly all pupils with dominant science interests and hobbies tend to have good social poise and are not classified as unusual in social behavior. (5) Approximately 60 per cent of the pupils with dominant science interests and hobbies are inclined to avoid the usual physical activities found in the typical secondary school. (6) All the pupils with dominant science interests and hobbies are readers of science literature. (7) Pupils with dominant science interests and hobbies are encouraged by parents or science teachers in their interests and hobbies.

Carlin, DelSanto, Gordon, Johnson, and Nash [7] sought to determine if there was a significant difference in abilities of pupils at various grade levels which would identify science minded students. Thirty-six students, each with an I.Q. of 120 or higher, were selected and matched, science-minded vs. non-science interested. The pairs were tested through use of standardized tests including the *Kuder Preference Test, Spaulding Picture Preference, Bell Emotional Adjustment Inventory,* and *Read General Science Test* and then interviewed by the writers. It was concluded that no ability difference was apparent, but the science interested person performed higher in science ability tests and was more aware of the role of science in every day life. Although the interests extended across all areas of science, there was one area the pupil liked best. The interests were not of the natural history or local immediate interest curiosity generating types which characterized the science disinterested student.

McCurdy [20] sought to identify significant characteristics and some background factors in the lives of superior science students. An inquiry form was developed and submitted to juries for editing. The form was sent to the top 600 students selected by the 1952 and 1953 *Science Talent Search.* The responses were contrasted with those of a group of generalists. Superior science students were described in terms of personality, attitudes and opinions, interests and high school performance. Their family backgrounds were also characterized. It was noted that the science teachers had great influence on science interest development.

Woodburn [28] examined the relationships between the science information possessed by ninth grade general science students and certain of their school and out-of-school science experiences. These factors included vacations in home background, social and economic conditions, sex differences, 4-H Club and Scout membership, interest in reading science books, amount of school science instruction prior to the ninth grade and intelligence. The study considered the amount of science information possessed by students upon entering the ninth grade, as well as the amount acquired during the course. The measuring instrument was the *Read General Science Test.* There were 1973 ninth grade students participating in the study. They were enrolled in 27 high schools located in large and small cities and villages. In addition to taking the *Read Test,* the students completed a questionnaire that enabled different categories of school and out-of-school experiences to be identified. Their teachers administered the tests, made their intelligence test scores available, and identified the students coming from the "best" and "poorest" homes.

The conclusions drawn were as follows:

1. Students upon entering the ninth grade general science course, are already familiar with a worthwhile portion of the science information customarily included in the course.
2. Whatever it is that gives a student an advantage on his intelligence tests also gives him an advantage in possessing pre-ninth grade science information.
3. Membership in Scout and 4-H organizations is accompanied by some factor that gives students an advantage on the *Read Test* and on intelligence tests.

4. Students from the "best" homes possess superior initial science information. However, students from the "best" and "poor" homes tend to gain the same amount of information through the ninth grade general science course.
5. The degree of relationship between the science information possessed by the students and their reported interest in reading science books is greater than the relatedness between such information and any other factor encountered in this study—the intelligence of the students being considered constant. "Best" and "poor" homes offered no difference in degree of stimulation toward reading science books.
6. Instruction in ninth grade general science tends to close the gap between those who enter the course with a minimum and a maximum amount of prior science instruction. It follows that a student who shows precocious ability in the acquisition of science information is not provided instructional experiences enabling him to maintain his relative superiority.

The major limitation of the investigation was imposed by the measuring instrument used. Only that science information which enabled a student to respond successfully to the items on the *Read Test* was considered in the study. The author conceded that many of the objectives and accomplishments claimed by general science teachers would require other means of identification and measurement.

Adrogna [1] examined the significance of sex, grade placement, and arithmetic development, singly and in combinations, as possible predictors of achievement in junior high school science. A random sample of 54 pupils chosen equally from grades 7, 8, 9 was obtained from 500 pupils enrolled in 5 New York City junior high schools. Pretest and retest general science scores were obtained. It was found that each of the factors under consideration was a potential predictor when used independently of the others after adjustment for differences in initial science scores and mental ages had been made. Combinations of factors were not more effective predictors.

STUDIES RELATING TO THE DEVELOPMENT OF CURRICULA AND SCIENCE COURSES

Research in this area includes studies which sought to give basis for inclusion of certain content in various courses in science as well as investigations leading to the development of specific courses of study.

Dzenowagis, McPherson, and Irwin [10] determined the prevalence of certain harmful health and safety misconceptions among a group of tenth grade girls. A health information inventory was constructed and administered to 250 girls representing the entire sophomore class of a high school for girls in a Massachusetts city. The inventory contained 216 harmful health and safety misconceptions. Students were required to choose one of the following responses for each item: true, sometimes true, false, don't know, don't understand. The statements in the list were validated by medical specialists and subject matter experts in the fields of health and safety education. Five inventory forms were constructed. Data obtained were analyzed to indicate, (1) the reliability coefficients of each inventory form, and (2) the percentage of all responses to each misconception in each inventory form.

Many harmful health and safety misconceptions were prevalent among the girls included in the study. Twenty-five per cent of the girls subscribed to 111 of 126 harmful health and safety misconceptions. The authors pointed out that whereas the validity of this instrument for measuring health and safety misconceptions was as good as it need be, the reliability of the instrument was probably quite low.

Giovannangeli [15] also provided some material of value to those interested in the content of biology and general science courses. His problem was to determine the accuracy of statements representing certain concepts concerning the use and effects of alcoholic beverages and to produce a reliable source of concepts to be used for study and reference by teachers and others interested in curriculum development. A jury was selected to evaluate the accuracy of 190 concepts and another jury was to evaluate the importance of the concepts for teaching in general education.

The author found only 18 concepts were judged true by all jury members and only one was found false by all. The concepts which could be taught as "true" were 139 in number; 13 were to be taught as "false," and the remainder as "debatable." Out of 93 concepts evaluated in terms of their importance in general education, 29 were rated as highly important, 48 as important, and 16 as being of little importance.

In an effort to ascertain implications for grade placement of physics principles, Johnson [19] studied achievement in physics at the junior high school, senior high school and junior college levels. Tests were given 845 students from 11 junior high school classes in general science, 12 senior high school physics classes, and 8 junior college classes of physical science survey courses. Content was from the areas of sound, static electricity and magnetism. Comparisons were made after statistical analysis through the use of analysis of variance and co-variance in which intelligence was held constant.

He found considerable unnecessary duplication in the development of understanding of principles of sound, static electricity, and magnetism between ninth grade general science, high school physics, and physical science survey courses at the college level. Johnson concluded that students who have completed ninth grade general science and high school physics probably cannot profit from a physical science survey course at the college level. Further, he concluded that students who have completed ninth grade general science probably cannot, under present instructional practices, profit from a physical science survey course at the college level.

Curtis [8] listed the mathematical terms which appeared in five textbooks in high school physics and those principles of physics which appeared in at least three of the five books. She then determined the number and type of mathematical terms needed to explain the physical principles. She found that to understand high school physics textbooks required the pupil have a knowledge of arithmetic, simple algebra, geometry and the fundamentals of trigonometry. The study of mechanics required the greatest amount of mathematics; the study of atomic energy required the least. The author recommended that mechanics be relegated to a later part of the course rather than be presented at the outset.

McKibben [21] analyzed the principles and activities of importance for general biology courses in high schools. A jury consisting of thirteen science specialists and 19 high school biology teachers was selected. The jury was asked to use the Ten Imperative Needs of Youth as criteria for evaluating a list of 300 principles of biological science. Each correspondent was asked to indicate whether, in his opinion, each principle was essential, desirable or undesirable for use in high school biology courses on the basis of how well it met the criteria employed.

A checklist was made of 93 significant principles and related activities based upon the jury findings. This checklist was sent to 15 science education specialists and 15 high school biology teachers. Each evaluator was asked to indicate whether, in his opinion, a given activity would contribute to an understanding of the principles with which it was listed. He was also asked to indicate to what extent this activity was suited to a high school course for general education and whether the activity would more appropriately be done as a demonstration, or as an individually performed laboratory experiment.

The following conclusions were drawn:

(1) There are 152 significant principles of biological sciences which constitute a sufficient number from which to select for high school biology courses for general education.
(2) There are sufficient activities which are well suited to developing understanding of a majority of the important principles of the biological sciences.
(3) For a few principles no contributory activities were found in textbooks, workbooks, and periodical literature. In addition, certain principles did not have activities which

were ideally or well-suited. Some of these principles may be developed by means of visual aids. An attempt should be made to discover, develop, and evaluate activities which contribute to these principles.

(4) A slight majority of the activities classified as ideal or well suited would more appropriately be performed as demonstrations than as individual laboratory activities.

STUDIES OF EXTRA-CURRICULAR SCIENCE ACTIVITIES

McPherson [22] sent questionnaires to selected Texas high schools and studied the literature as it related to science clubs for the period since 1940. He found that the science clubs were not highly specialized but were related to the general areas of science as taught in the schools. It was also noted that the absence of a science club did not necessarily indicate a lack of interest in such activity, but values derived from such club work seemed to indicate a need for enlarging the scope of this type of science activity.

Gladieux [16] prepared questionnaires concerning science clubs, regional science congresses, *Science Talent Search,* and the *New York State Science Congress.* Sampling was made in public schools of New York, exclusive of New York City, and student contestants in the *New York Science Congress.* Although the investigation was designed to determine status and outcomes of extra class activities, the author makes as his fundamental conclusion —the most important single factor involved in the success of an extra-class science activity appears to be the availability and willingness of a science teacher to assume the responsibility of sponsorship. A factor which reduces the effectiveness of science teachers directing such activities is that they are assigned too many non-teaching, non-science duties.

STUDIES RELATING TO SCIENCE TEACHING FACILITIES AND MATERIALS

Sullivan [27] surveyed the laboratory facilities in ten Indiana high schools for the teaching of three selected units in biology by means of a checklist. He found that while 8 of the 10 had inadequate facilities for teaching elementary bacteriology, there were adequate facilities in 9 of the 10 schools for dissection of preserved animals and quite complete facilities in all the schools for laboratory instruction in cell study.

In another Indiana study, Hoch [18] surveyed biology teachers to determine their evaluation of free-loan films and those of regular educational producers. Questionnaires were sent to a stratified random sample of all public and parochial schools. The 200 schools produced the information that the smaller high schools made greater use of free-loan films than the larger high schools. In addition, 54 per cent of the teachers thought that free-loan films were better suited to their needs.

Mallinson, Sturm, and Mallinson [24] analyzed the reading difficulty of recently published textbooks for general physical science and earth science by using a modification of the Flesch technique. Eleven physical science and seven earth science textbooks were selected and analyzed as follows:

(1) One sample passage was selected for each 100 pages or fraction thereof in the total book, but not less than five samples were used.

(2) The total number of pages in the book was divided by the number of samples needed (to divide the book into equal sections) and the samples were then taken for a page that was determined by using a table of random numbers.

(3) A 100-word sample was obtained by counting from the first word of the first new paragraph on the selected page.

(4) The sample was then translated into a reading-difficulty score by applying the Flesch formula.

(5) The reading-difficulty score was converted into a grade-level value of reading difficulty.

It was found that the levels of reading-difficulty varied greatly from book to book, as well as within individual books. Most books were too difficult for the students for whom they were designed. The early parts of the books were not consistently lower in difficulty than the end; hence, no provision was made for growth in reading ability.

STUDIES CONCERNED WITH TEACHING METHODS

Anderson, Montgomery, Smith, and Anderson [3] conducted an investigation comparing pupil achievement in biology when films are used or not used with traditional class procedures. Comparisons were made between classes in which no films were shown; those showing films but for which teachers made their own preparations for the showings, and classes in which film showings were bolstered by emphasizing the principles covered or stressed in each film. The authors state there was some evidence that the Films-with-Principles-Stressed Method yielded results somewhat superior to the Film Method, and that the Film Method yielded results somewhat superior to a conventional method as used in Control Group. This study has indicated that a choice of films in harmony with the objectives of instruction in a particular academic area is capable of yielding superior results in learning if the proper choice of films is accompanied by realistic film utilization which emphasizes selected objectives of instruction in an academic area. Since only one objective of instruction was selected for emphasis in this study, it is to be expected that film-utilization plans which cover all of the major objectives of instruction in an area will produce even greater learning on the part of students in science and other areas of instruction.

Frasier [12] concluded that seventh grade pupils do not naturally have scientific attitudes nor are they able to apply the scientific method. He did find that these outcomes were attainable when specifically taught for and without loss of traditional subject matter knowledge. These results came from a controlled experiment involving 1000 seventh grade pupils. All children were pre and post tested but only the members of the experimental classes were exposed to the teaching and supervisory practices.

STUDIES RELATING TO EVALUATION OF SCIENCE INSTRUCTION

Two investigations into New York State Regents Examinations were reported. Alberti [2] analyzed the June 1950 examination in chemistry for reliability, consistency, and validity. He found the examination more reliable than teacher-made tests and more valid in its measure of principles. Data failed to show consistency or validity in problem-solving measurement.

Service [26] carried out an investigation with the June 1950 Regents Examination in Earth Science. He found that the examinations were not valid, reliable, or consistent. He decided that it seemed likely that if more emphasis were placed on facts there would be less likelihood a student would achieve the broader objectives of science teaching. This statement was based on the assumption that Part I of the examination measured chiefly factual information and Part II the other objectives.

An evaluation study of an entirely different nature was contributed by the Science Council of the St. Louis Public High Schools [25]. The Council sent questionnaires to 168 firms and industries in St. Louis and analyzed the 60 per cent completed returns. The results showed that among the vocations listed, bricklayers and plumbers were found to need science and mathematics least. However, one-fourth of the respondents stated that some background in these areas would be desirable for these two vocations.

STUDIES IN THE TRAINING OF SCIENCE TEACHERS

The prediction of teacher effectiveness has been a persistent problem in teacher training. Beck [5] dealt with one aspect of this problem by seeking to identify superior policies and practices in student teaching, and to plan a student teaching program for prospective secondary school science teachers based on the findings of his study. Data for this study were obtained through use of three forms of a questionnaire, and

through personal interviews. Thirty-two of the 44 colleges and universities in Ohio which had student teachers participated in the study. Beck found that supervision of student teaching is a minor part of the assigned duties of college and university staff members reported. A school with an enrollment of less than 800 students, few pupils in the upper six grades, with three or fewer student teachers assigned in science, is the typical high school which was utilized for student teaching at the time of the study. Opportunities for professional laboratory experiences on the part of student teachers, aside from classroom teaching are, in general, limited. Student teachers are relatively free in the selection of methods of teaching and instructional materials. Frequent, unscheduled, follow-up conferences between supervising teachers and their student teachers are common. College and university supervisors, in general, observe their student teachers in science from three to five times during their student teaching assignments, and hold as many conferences with the student teacher. The follow-up conferences are, in general, about thirty minutes in duration. A program for student teaching was proposed.

Droullard [9] studied the pre-service and in-service science education programs of Iowa secondary school science teachers. His problem was to reveal the science subject-matter backgrounds of Iowa secondary school science teachers, to compare teaching assignments among teachers of biology, chemistry, general science, and physics, and to obtain information on the in-service education of Iowa secondary school science teachers. The procedure was to construct a questionnaire which was then validated by a jury and mailed to a stratified random sample of science teachers. Of the 1,418 secondary science teachers in Iowa in 1953–54, instruments were sent to 400, with a 72 per cent response. His major findings and conclusions were that Iowa science teachers had more training in chemistry than physics, but taught more physics than chemistry. General science was taught by 56.2 per cent of the science teachers, biology by 55.9 per cent, physics by 36.4 per cent, and chemistry by 21.3 per cent. Biology teachers had a mean of 21.7 semester hours of biology. Fifty and eight tenths per cent of the science teaching trainees taking undergraduate work in Iowa were graduates of non-public schools of Iowa; masters degrees were held by 22 per cent of the teachers; and 93 per cent had at least a bachelors degree. Only 17 of 281 science teachers reported in-service education programs in their schools. Ninety-three of 263 science teachers indicated no special activity during the summer of 1953 to increase their science teaching competence.

Georgison [13] attempted to determine the preparation needed for science teachers to effectively teach science. Using a questionnaire sent to teachers in six California communities, he found teachers felt they were adequately prepared for field trips, demonstration and experiments, and that their student teaching experiences were adequate. However, teachers felt they needed additional experiences in the maintenance of science equipment, directing pupil projects, and in selecting and ordering science materials. Teachers also felt that observation of experienced science teachers would have been helpful.

Gifford [14] made a study of 20 practice teachers of the Department of the Teaching of Science at Teachers College, Columbia University, in the spring session of 1949. The evidence was gathered through written questionnaires, individual conferences, weekly report forms, and classroom observations of their teaching. The results of the diagnostic speech examination, comprehensive science examination, and the number of hours spent in student teaching were also used. Even though the evidence was not conclusive, it seemed that all student teachers made some changes in a positive direction during the semester of teaching.

There were more changes from originally weak positions, relative to characteristics, than from original positions which seemed strong. The number of changes in a negative direction were few.

INVESTIGATIONS OF TRENDS IN SCIENCE EDUCATION

Trends in science education in Michigan were reported by Mallinson [23]. In order to obtain the necessary information, questionnaires were sent to one half of the high school administrators in Michigan. Also, one questionnaire was sent to the junior high school science teacher and one to the senior high school science teacher in the school system of each of the administrators. The selection of respondents was accomplished by a random sampling technique.

Over eighty per cent of the questionnaires sent to the administrators were returned (209), and over sixty per cent of those sent to the teachers were returned (312).

The findings were as follows:

(1) The majority of teachers in class A, B, and C schools teach more than one science, 90 per cent of the combinations fall into four categories of: (a) Biology and General Science (b) Biology, General Science, and Physical Education (c) Chemistry, Physics, and Mathematics, and (d) Chemistry, Physics, Biology, and General Science.
(2) As many as four different science courses were, in some cases, taught by one teacher.
(3) In most cases, the courses other than science which were taught by a science teacher, were mathematics or physical education.
(4) Many teachers who are teaching only one science do not have a major or minor preparation in the subject taught. This is particularly true in small schools and in the subject of physics. Few teachers of general science have the required or desired breadth of training. Most of them are specialists in one subject.
(5) In the majority of Class A, B, and C schools, administrators emphasized that they wanted science teachers who had broad training in science rather than a narrow background. They wanted teachers who are capable of handling any and all science assignments.

Haupt [17] traced the development of secondary school science, especially for grades 7, 8 and 9 for the period between 1900 and 1954. Changes in theories and practices were traced through a comparison of objectives listed in studies covering this period and teaching methods employed. He found less agreement as to methods and purposes today than in previous years. He noted a trend toward exploration, differentiation, socialization and articulation with less emphasis on college or vocational preparation.

Flannigan [11] proposed (1) to give a current picture of the status of general education science in the public high schools of the United States, grades 9–12, through study of (a) the place of general education science in the curricula of sample schools, (b) the methods used in teaching such courses, (c) the methods of selection of content, and (d) an evaluation of the general education science objectives of the schools in which such courses are taught and (2) to show how these general education science courses compare in the above areas with the usual conventional science courses: general science, general biology, elementary physics, and elementary chemistry.

A random sample of 800 public high schools was used. Of the 800 schools, 117 returned completed checklists in which 216 courses were reported representing 47 different types of courses.

On the basis of information supplied by the 117 schools via the checklists, the following conclusions were drawn: (1) General education science courses, especially those used to replace the conventional courses in chemistry and physics, are increasing in the public high schools. This is based on the starting dates of courses mentioned and from change in enrollment in the courses. (2) The great majority of these courses are developed for the junior and senior years. This would seem to indicate that many schools are fairly well satisfied with freshman general science and sophomore general biology but are trying to form a four-year science sequence in terms of general education. However, a

considerable number of these courses enroll sophomores, indicating that general biology as a sophomore subject has not been nationally accepted. (3) Laboratory work is included in three of every four of the general education courses studied. In seven of every ten of these lab courses, the students are required to work individually or in pairs. (4) More than six of every ten general education science courses are accepted by colleges for entrance credit. (5) Principals prefer men teachers to women for their general education science courses in a ratio of about seven to three. (6) General education science courses are not considered courses for the slow learner. Only about 3 per cent of the sample courses are used for this purpose. (7) The subject-matter survey course is still the most popular means of presenting general education science material in the secondary school. (8) No general agreement is indicated as to specific topics to be included in general education science courses due in part to differences in environment, type of student served, and geographical location.

SUMMARY

In comparison with past years, the quantity and general quality of the research published seems to be declining. Only 11 studies were found in 41 of the journals examined. Only 7 journals published studies that could be classified as research, even by liberal standards. Four of the 11 studies were published in *Science Education* which indicates that the remaining 40 journals can claim only 7 research reports in a year of publication. Most of the research studies reported here are in the category of either Trends, Curriculum, Pupil Interests, Evaluation of Instruction, and Teacher Training. Much remains to be done in the fields of Methodology, Scientific Method, Scientific Attitudes, and Psychology of Learning.

The techniques of research reported in both published and unpublished studies can stand improvement. There was a noticeable need of clearer statements of the problems, definition of terms, population studied, discussion of research methods employed, description of measuring devices, statistical treatment, and interpretation of statistical findings.

It is recommended that steps be taken by NARST to improve the quality and encourage a larger production of research. A program of sponsored, patterned, and planned research should be developed. Perhaps grants-in-aid may be obtained. Sponsoring agencies can be consulted for suggested studies in the areas of their interests and needs. Certainly there is a need for research in the areas of motivation of pupils in pursuing the study of science, teaching methods and materials, and the man power shortage of science teachers and scientists. Concerted action is needed to determine why research has fallen off and also, what can be done to remedy the conditions causing it.

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REVIEW OF RECENT RESEARCH IN THE TEACHING OF SCIENCE AT THE COLLEGE. LEVEL III

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STUDIES IN TESTING AND EVALUATION OF SCIENCE TEACHING

A RELATIVELY unexploited area of research in science education at the college level is the general field of testing and evaluation. While there are a few "landmark studies" which have dealt with areas of content mastery; attitudes, appreciations, insights, formation of principles and con-

cepts, and the likes have not yet been adequately dealt with.

Trends in testing and evaluation of science education programs continue, with a few notable exceptions, to be in terms of subject matter mastery and retention of the facts of science. Achievement in any educational enterprise can be appraised only in terms of the goals sought. Although a considerable number of studies reported a wide range of goals, including attitudes, appreciations, insights, and the like, most of the current studies were concerned with externally patterned or stereotyped behavior which is no longer considered a valid index of desired outcomes. A few studies have been concerned with creative expression, and the exercise of intelligence or application of scientific principles, methods, habits, and the like in molding a changing environment in the service of society. A very few studies have been concerned with the individuals behavioral changes as he makes the necessary adjustments to the environment.

One writer who has been very active in this field, Kruglak [7] utilized paper-pencil analogs of laboratory performance tests to discover the extent to which ability to solve a laboratory problem on paper is related to the ability to solve the same problem using apparatus and materials. His procedure involved construction of three forms of a laboratory test in electricity and administration to pre-medical students at the University of Minnesota. The items on the essay and multiple-choice forms were made as analagous as possible to the corresponding performance tests. Extensive use was made of photographic technique to simulate the actual laboratory situation. Kruglak found, in general, a low degree of relationship between the performance and other forms of the test.

Lampkin [11], who was concerned with aspects of scientific method, studied the validity of test items that were used to measure the ability to find a pattern in data. In this connection, he studied 26 tests which contained 409 number series items, and discussed the validity of each particular item. He concluded that use of number series items did not provide valid examination, and that further use of them was questionable.

An investigation of the effectiveness of the science sequence in certain teachers colleges was reported by Lewis [13] who utilized pre and post tests with 237 students from eight teachers colleges in northeastern states. A statistically significant increase was found in problem-solving abilities at the termination of the science sequence. Score gains were not affected significantly by variations in the number of years of pre-college training. The eight college groups made equivalent gains in factual knowledge but different gains in problem-solving ability.

Anfinson [2] set out to refine objective tests for the non-subject matter goals of science in college general education science courses through the use of statistical analysis. He attempted to determine whether science teachers could produce valid instruments for measuring student status with regard to non-subject matter goals of general education science courses. Anfinson produced instruments through the use of teachers in a science education seminar at Colorado State College of Education, and refined these in the general education classes at the same college and three midwestern colleges. The teachers in the science seminar demonstrated the ability, as a group, to produce valid and reliable instruments for measuring the behavior of college students with regard to non-subject matter goals of science for general education.

Nedelsky [18] attempted to resolve the problem: how can a student's selection of wrong responses to multiple choice items which he answers incorrectly serve as a further measure of his achievement or lack of achievement? In this study Nedelsky constructed test items in which the responses were classified R, right answer; F, obviously wrong having little appeal to all but poorest students, and W, wrong re-

sponses other than the F type. He found that the poorer students exhibited no reliably measurable differences in their ability to select correct answers, but did show considerable difference in their ability to reject grossly wrong answers, and that the two abilities were probably imperfectly correlated. He concluded that if the main or perhaps the only progress some students can now make with respect to certain parts or aspects of a field is in learning to avoid gross misjudgment or error, such progress should be measured or rewarded.

In an attempt to devise an instrument to predict the probability of academic success in engineering, Ahmann [1] dealt with students who transferred from other institutions of higher learning to Iowa State College. Data were obtained on 804 male engineering transfer students since 1946; quantitative raw scores on the *ACE Psychological Examination* (1945 edition), high school grade point average, raw scores on the *USAFI Test on Correctness and Effectiveness of Expression* (College Level), prior college achievement, and first-quarter grade point average at Iowa State College. Veterans and non-veterans were compared, and students coming from junior colleges were compared with transferring students from other colleges. Bi-serial correlation coefficients were made to evaluate the effectiveness of the various predictive criteria. Multiple bi-serial correlation coefficients were used to evaluate various combinations of predictive criteria. In this study, the first quarter grade point average at ISC was the best predictive criteria, and the linguistic score on the ACE test the poorest. The prediction was greatly improved as the number of criteria was increased. Tables which were worked out would be useful in counseling students as to the probability of their success in a given situation.

STUDIES RELATED TO THE CURRICULUM

Harlow [6] developed instruments for use in locating and describing the opinions of instructors about college programs in general education science, and applied the instrument, a questionnaire, to 23 colleges and universities in Oklahoma. Checklists were prepared which dealt with the aims of general education programs in science, characteristics of teachers, the curriculum, the laboratory, and the library.

Seifriz [20] made an analysis of scientific publications, and the opinions of other scientists about scientific publications to support the identified trends in university learning and the resulting effects. The author believed that scientists and other scholars did not have adequate opportunities, in the present-day university, to develop broad-mindedness, imagination, humility, and deep devotion. He concluded that a "new university, a guild of scholars as at Padua" is needed if science and academic learning are to function. This new university would provide enlightenment which is more than mere knowledge, "enlightenment is knowledge softened by understanding." He ventured the opinion that perhaps we have accepted the adage that "knowledge is power" too long, and now begin to realize its inadequacies.

Franks [5] developed a two-year experimental general education science program based on student interests and problems. He found that, for many non-science majors, the specialized science courses are unsatisfactory. The "block and gap" approach appeared to be better than superficial survey or diluted orthodox science courses. Student suggestions and criticisms were found to be invaluable in locating weaknesses in the course, and it was concluded that the general education science program should be flexible enough to allow for capitalization upon the special interests and capacities of students.

Mecay [17] attempted to determine the extent to which a knowledge of genetics is needed by the layman in order to read with comprehension, understanding, and appreciation the articles on the subject which appear in the non-technical periodicals

having the greatest circulation. The documentary frequency type of the normative survey method of research was used, and complete issues of 12 non-technical magazines published during the period 1949-1953 were the sources of data. The author concluded that the significance of the 602 articles found in the 1,520 issues lies in the fact that a highly specialized subject, such as genetics, appealed to and was made available to the general reader. Two out of every four articles presenting a genetic topic pertained to animal genetics, while one article out of every four pertained to either human or plant genetics. The vocabulary burden of words and phrases needed to read the 602 articles was relatively small. A knowledge of at least 22 of the basic principles of genetics was needed for the general reader to comprehend the context of all of the genetics articles collected in this study. In every article a knowledge of the principles and hypotheses of genetics was assumed by the writer of the article.

Washton [29] sought to determine the applications of several biological principles to a generalization, concept, principle, or problem in the physical sciences: astronomy, chemistry, geology, or physics. A sample of five principles of biology for general education was listed in a questionnaire. Fifty questionnaires were returned by members of the National Association for Research in Science Teaching representing all of the areas in the natural sciences. They were asked to list those generalizations or principles in the physical sciences which would help students understand the specified biological principles. This was done individually for each of the biological principles that appeared in the questionnaire. The findings in this study indicate that several biological principles may be applied to concepts or topics pertaining to energy, chemical change, catalysis, molecular theory, disatrophism, erosion, orogency, isostasy, and mechanics of liquid. It was suggested that experimental syllabi be developed for science courses in general education which would seek to apply principles across the field of science.

STUDIES RELATED TO TEACHING TECHNIQUES

Mason and Angell [15] selected 93 students, enrolled in five laboratory sections in the first of a three term course in biological science, and utilized a teaching variable of a 20-minute discussion period carried on during certain laboratory sections. The instructor assumed the responsibility of directing the discussion period, and an attempt was made to establish rapport with the students and maintain situations in which they would feel free to express themselves. Students in the laboratory periods in which the discussion activity was carried on did slightly better than did students in the control group in which the discussion activity was not a part of the instructional program. Students participating in the discussion activity, as indicated by their responses to an unsigned questionnaire felt that the discussion period not only provided experiences which were helpful with respect to such objectives as acquisition of facts and ability to solve problems, but also opportunities for growth in some of the more general aims of education.

In an integrated freshman college science course at Amherst College, Arons [3] indicated that a special effort was made to break down the kind of study habits which orient students toward "getting the answers," and mechanical manipulation without understanding. Tests were given in which the student would have to explain his rationale for each important step in an experiment and mathematical proof. Students were motivated to acquire understanding of scientific concepts through practicing an awareness of the meaning and role of each idea in a broad pattern. Course emphasis was upon intellectual training and critical thinking rather than accumulation of information.

Mason and Warrington [16] compared two methods of teaching students in a one

hour recitation period with respect to acquisition of scientific thinking ability. In the experimental group analysis and evaluation of current scientific articles was the means used to acquire the stated objective. This group was compared with a control group which was mainly concerned with location of student problems and acquiring factual information. Although the students who had training in critical analysis felt they had become more scientific in their thinking, this was not indicated by the measuring instruments used. The group concerned with actual course content showed somewhat higher accomplishment in term examinations. The authors felt these results may have been due to a too short period of application of the experimental method and inadequate relationship between the scientific articles and the course content.

Kruglak [8] attempted to determine the degree to which laboratory achievement is a function of the number of partners. The control group worked singly, in pairs, or in quartets, and achievement in all groups was compared. He found that laboratory achievement in general physics, as defined by mean score on multiple choice and performance tests, is not measurably influenced by the laboratory instructor; students working in quartets earn better average grades on laboratory reports written in the laboratory than do students working singly or in pairs; laboratory grades based primarily on written laboratory reports vary significantly from instructor to instructor; scholastic aptitude tests are poor or unreliable predictors of laboratory achievement in physics; and academic standing is a fair predictor of laboratory grades.

In another study, Kruglak [9] attempted to discover the effect of high school physics, sex differences, and college laboratory instruction on achievement in college physics. Kruglak developed tests on identification of apparatus, functions of apparatus, and miscellaneous aspects of physics laboratory work. He constructed five alternative multiple choice items based on pictures. Pretests were used, as also were performance tests. Kruglak found that there were significant sex differences in the scores; students who took the course with laboratory work had higher scores on the identification test; laboratory work in high school physics appeared to have little influence on paper-pencil tests; and students who had had laboratory experiences in high school physics made significantly higher scores on the laboratory performance tests.

In a study of the problem of whether students in elementary engineering physics benefit measurably from special instruction in the reading and interpretation of the physics textbook, Kruglak [10] used 445 students at the University of Minnesota. The control group was taught by the lecture-demonstration method, the experimental group by the same method plus the instructor reading and interpreting the textbook part of the time. No significant differences were found at the 5 per cent level for the two groups on standard tests or for the final grades. The author felt that further study was necessary and that special reading tests should be used in any further study of this area.

Wallin [21] attempted to discover the teaching values of labeling and using commercially prepared biology drawings as compared with the achievement gain in factual knowledge made by students who completed and labeled free-hand drawings. The study was carried out in a general biology class over two school years at State University Teachers College, Brockton, New York. One hundred ninety-five sophomore students were the subjects. Students using commercial drawings equalled or surpassed the achievement gain in factual information of students who made their own drawings.

MISCELLANEOUS STUDIES

Lawrence [12] studied certain problems in articulation between high school and college chemistry instruction. A two-part questionnaire was given to a random sam-

pling of 1,000 freshman science students at Cornell University in 1953–1954.

Part I asked the students to consider and evaluate the "Relative Importance of Various Factors for Success in First-Year College Chemistry." The students considered the following factors necessary for success in the following order of importance: (1) Ability to use clear, concise English (2) Interest in chemistry (3) Skill in laboratory work (4) Minimum of fundamental principles (5) Interest and ability in mathematics (6) Legible handwriting and correct spelling. Final statistical results were not available at the time of writing.

Part II of the questionnaire was designed to obtain the "Students' Ranking of the Relative Importance of Various Traits in Teachers of Chemistry." The importance of the traits were ranked as follows: (1) Clarity of explanation (2) Mastery of subject (3) Enthusiasm and interest such that students "catch" it (4) Pleasant student-instructor relations (both in and out of class) (5) Poise and control of classroom (6) Definite interest in student study habits (7) Tendency to give moderate assignments and tests (8) Tendency to give maximum assignments and tests (9) Tendency to give minimum assignments and tests (10) Personal appearance.

Mallinson and Sams [14] sought to determine whether or not a knowledge of science had any relationship to achievement in general psychology. *The Ohio State Psychological Examination,* Form 21 (O C A), Minnesota State Board Examinations (1947) in biology and chemistry, and an achievement examination in general psychology were used as measures on 847 students who participated in the study carried out over a three year period. Simple correlation coefficients were computed between scores on the various tests. This was followed by the calculation of partial coefficients of correlation between various sets of scores, holding constant the influence of the other two sets.

The authors summarized: it seems reasonable to state that achievement in general psychology is influenced to a greater extent by intelligence than by knowledge of scientific topics and principles that may be related to that course. Recommendations were made to determine the areas of biology most necessary for effective learning in psychology and in what way these topics could be best integrated into the general psychology course.

Wolfle [23] made a comprehensive study of present needs of highly specialized and educated specialists and forecast needs during the decades ahead. This study was based on the collection of vast amount of data, compilation of the data into tables, and derivation of conclusions therefrom. With the possible exception of physicians and dentists, and to a somewhat lesser degree lawyers and engineers, most employed college graduates, Wolfle found, are working in fields other than their major as undergraduates. "To give strictly vocational training at the undergraduate level is always a temptation but figures indicate that sizeable portions of most professional groups have entered their professions after obtaining an undergraduate degree in some other field." Through adequate guidance of both parents and their children, more of the gifted should be encouraged to obtain a college education. This is an excellent report which calls attention to a problem which has tremendous implications for all fields of education, including science education.

The two studies which follow, though not strictly in the area of science education, are related to science teaching objectives in a broad sense. They are included for their possible value to researchers interested in concept formation and attitude change or development.

Carpenter [4] attempted to gauge the effect of varying amounts of verbal reinforcement on concept formation. Ninety-two graduate students were asked to select 8 wooden blocks from a pool of 19 to complete the membership of two classes. A sample block for each class was used as a guide. Stimuli differed in color, size, and

in shape and weight. Subjects had to combine dimensions, size, and height to achieve correct classification. Four groups were given varying amounts of reinforcement to all correct choices. Data consisted of the number of trials and number of minutes to reach an errorless trial. There was a clear tendency to acquire the concepts in less time as the amount of reinforcement continued. The claim that concept formation is qualitatively different from less "complex" learning was not supported. When subjects were primarily "set" to acquire only a functional (non-verbal) knowledge of the concepts they failed 25 per cent of the time to render adequate definition of the acquired concept . . . the majority of whom were seniors. Fifty per cent of the colleges indicated use of an individualized approach, rather than cooperative planning. Demonstration and student supplies in the area of chemistry, biology, physics, and audio-visual materials appeared to be adequate for the activities required in the individual colleges.

Robinson [19] analyzed the relationship between the emotional intensity of a persuasive communication and the effectiveness of the communication in producing attitude change. A secondary purpose of the study was to ascertain the interaction between individual pre-dispositions and the stimulus material in the determination of patterns of response. Three versions of an Army orientation film were prepared which differed in the amount of anxiety-producing stimulus producing material by editing out selected portions of the original film. At each of several experimental sessions, the participants were randomly selected and assigned four identical rooms with built-in projection facilities. Each of three groups viewed one version of the film, and the fourth served as a control. Prior to the film presentations, the group took the *Rosenzweig Picture-Frustration Test,* and after viewing the films the students filled out a series of three attitude scales and a questionnaire. Robinson found that there was evidence of systematic change of attitude as a result of increased communication intensity. However, an analysis of variance between experimental groups failed to yield significant differences. On the other hand, when an analysis of co-variance was performed, using the scores obtained on the *Picture Frustration Test* as the "matching variable," several significant differences did appear in the predicted direction. The major recommendation of the study related to the necessity of examining personality characteristics of audience members whenever attempting to predict attitude change resulting from emotional appeals. The findings emphasized the fact that mere analysis of stimulus material (the communication content) is not, in itself, a sufficient basis for predicting the effects of emotional appeals.

SUMMARY

There appears to be an unhappy dearth of significant research in college level general education science for the period covered by this review. This deficit has been commented upon by previous reviewers.

Research in science education is influenced by a number of factors. Continued development of research in any field must necessarily involve conceptual models, theoretical considerations, philosophical and social foundations, and structurization of newer and improved models of research design. Very little definitive research in college level general education science was reported in the literature examined. Much of the current research deals with the nature of views held by students, teachers, administrators, and "experts."

There appears to have been little impact from recent developments in the behavioral sciences, cooperative inter and multi-disciplinary research, group dynamics and processes, organismic and field psychologies, use of factorial design and the tools of analysis of variance and co-variance to bolster the controlled experiment, action research, preparation of conceptual and other models, or awareness of the newer

statistical tools. There is considerable evidence that many of the "landmark" studies need to be repeated using the new approaches now available.

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CONFERENCE ON SCIENTIFIC MANPOWER*

NEW YORK CITY, DECEMBER 26, 1956
Hotel Statler, East Room

PROGRAM

4:00 P.M. PAUL B. SEARS, Yale University, New Haven, Connecticut, Presiding.

1. The Program of the National Committee for the Development of Scientists and Engineers. HOWARD L. BEVIS, Chairman, National Committee for the Development of Scientists and Engineers, Washington, D. C.
2. Discussion
   a. Implications for Physical Sciences. J. C. WARNER, President, Carnegie Institute of Technology, Pittsburgh, Pennsylvania
   b. Implications for Engineering. EARL P. STEVENSON, President, Arthur D. Little, Inc., Cambridge, Massachusetts
   c. Implications for Life Sciences. MILTON O. LEE, Executive Secretary, Federation of American Societies for Experimental Biology, Washington, D. C.

* In conjunction with the 123rd meeting of the American Association for the Advancement of Science.

NATIONAL FOUNDATION FOR INFANTILE PARALYSIS GRANTS ASSIST PROFESSIONAL EDUCATION

THE National Foundation for Infantile Paralysis, through the Division of Professional Education provides assistance to colleges and universities through grants from March of Dimes funds to enlarge or improve professional education in fields related to patient care.

The Division of Professional Education is concerned with four major areas of activity: the preparation of professional personnel; the improvement of professional education standards in cooperation with agencies, associations, and institutions; assistance to improve or enlarge teaching programs for professional personnel; and the preparation and distribution of professional education media, such as literature, films, and exhibits. Grants are made by the Board of Trustees of the National Foundation acting upon the recommendation of its President and the appropriate advisory committee.

Grants to support professional education provide for a stated budget for each year included. In long term grants, the budget is reviewed annually and requests for changes are submitted to the National Foundation for approval. The National Foundation does not make grants to relieve normal institutional budgets.

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Colleges and universities desiring grant assistance should initiate the application by letter in which is contained a brief statement as to the nature of the proposed project, a concise description of the plan of execution of the proposed project, and a statement of the financial requirements itemized in relation to salaries, equipment, supplies and materials, and miscellaneous. This information will serve as a basis for further discussion during a visit to the proposed applicant by an official representative of the National Foundation. This letter is not treated as an official application for a grant, but a letter of inquiry only.

The actual application for a grant is made on an official form which is provided the applicant after the preliminary letter and discussion. Applications for grants are usually considered semi-annually in the Spring and Fall. In order to be presented at the regular meetings of the Advisory Committees and the Board of Trustees, applications must be filed in the office of the National Foundation on or before January 1st or July 1st preceding the meetings. All such applications subsequently approved become effective the following July 1st or January 1st, respectively.

For further information write:

Division of Professional Education
National Foundation for Infantile
Paralysis
120 Broadway
New York City, N. Y.

SAMUEL RALPH POWERS

To Samuel Ralph Powers is accorded the Third Science Education Recognition Award. Dr. Powers is probably the best known of all American science education leaders during the last thirty years.

Professor Samuel Ralph Powers was born in Petersburg, Illinois, May 16, 1887, the son of John William and Nancy Terence (Erwin) Powers. He married Eda May Olds October 10, 1910. Their children included Philip Nathan, Merrill E., Samuel Ralph, Jr., and Karol R. (deceased).

Dr. Powers graduated from Illinois Normal University, Normal, Illinois, in 1910. He received a B.A. degree from the University of Illinois in 1910 and M.A. and Ph.D. degrees from the University of Minnesota in 1919 and 1923 respectively.

Teaching experience includes rural school, Menard County, Illinois 1905–1908; Chemistry and Head of Science Department, Garfield High School, Terre Haute, Indiana, 1912–16; Science instructor, University High School, University of Minnesota 1916–20; Professor of Education, University of Arkansas, Fayetteville, Arkansas, 1920–21; Instructor in University of Minnesota, 1921–23; Teachers College, Columbia University, 1923–52 where he served as Associate Professor (1923–28) and as Professor and Head of the Natural Science Department, 1928–1952. He taught a number of summer sessions at the Colorado State College of Education, Greeley, Colorado (1928–39).

Dr. Powers served as Lecturer and Consultant on Teacher Education, Men's Teacher Training College and Ministry of Education, Cairo, Egypt, 1954–55. (Under the U. S. Educational Exchange Grant authorized by the Fulbright Act). During the present semester, Dr. Powers is Visiting Professor in the School of Education, University of Florida, Gainesville, Florida.

Membership in organizations include such organizations as the National Association for Research in Science Teaching, National Council on Elementary Science, National Science Teachers Association, Central Association of Science and Mathematics Teachers, National Biology Teachers Association, National Education Association, American Education Research Association, National Society for the Study of Education, American Chemical Society, American Association for the Advancement of Science (Fellow), Phi Delta Kappa, Tau Kappa Epsilon, and Sons of the American Revolution.

Many years ago as Head of the Natural Science Department at Teachers College, Dr. Powers initiated and brought to fruition the organization of a professional group of eastern science education leaders now designated as the Association for the Education of Teachers in Science.

Dr. Powers is a charter member of NARST and was one of the small group responsible for its organization and initial success. He served as its first Secretary-Treasurer 1928–37, and as President 1938–39. For many years Dr. Powers was probably the most active of all members in NARST. His contributions here probably exceed those of any other member. Dr. Powers was Chairman of the Chemistry Section of the Central Association of Science and Mathematics Teachers in 1917; member of the Board of Directors of the National Science Teachers Association, 1949–52; Vice-President and Chairman of Section Q (Education) of the AAAS 1951; member of N.E.A. Committee on Reorganization of Science Teaching in the Secondary Schools, Bureau of Education Bulletin No. 26, 1921; Chairman of the Committee on the Teaching of Science (1929–32) of the National Society for the Study of Education which published the 32nd Yearbook and a member of the committees of two other yearbooks of NSSE;

member of committee of 25th Yearbook "Backgrounds from Science for the Education of Teachers" of the National Society of College Teachers of Education, 1937; chairman of the Committee on Research in the Teaching of Science and Mathematics, American Educational Research Association, 1939–42 and 1942–45; Chairman of Committee on Preparation of Report on Science Course Content and Teaching Apparatus Used in Schools and Colleges in the United States, UNESCO Preparatory Commission 1946; Chairman of the Subcommittee on Teacher Education of the National Committee of Science Teaching, American Council of Science Teachers of the National Education Association (now National Science Teachers Association), 1942; Contributor to Golden Jubilee Number—*Half Century of Chemical Education in America 1876–1926,* American Chemical Society, 1926; Administrative officer of the Bureau of Educational Research in Science, financed in part by the General Education Board, Teachers College, Columbia University, 1934–42; Special Consultant, Industrial Personnel Division, Army Service Forces, War Department, 1942–1945; Editorial Advisory Board of World Book Encyclopedia; Chairman, Advisory Editorial Board Grolier *Book of Popular Science;* Consultant Audio-Visual Section, Bureau of Medicine, U. S. Navy, 1952.

Dr. Powers is the author of some 70 articles in various magazines, thus too numerous to list here. He is the co-author of the Ginn and Company's *Adventuring in Science* Series of Junior High School textbooks (*Man's Control of His Environment,* 1934; *This Changing World,* 1934; *World Around Us,* 1934; *Exploring Our World,* 1946, 1953; *Our World Changes,* 1946, 1953; *Adventuring in Science,* 1940; *Using Our World,* 1946, 1953; and *Our World and Science,* 1941, 1946, 1953), with their accompanying *Direct Activities* workbooks (co-authors were Elsie Flint Neuner, Herbert Bascom Bruner, and John Hodgdon Bradley); Editorial Collaborator for *Man and His Physical Universe* and *Man and His Biological Universe* (Ginn and Company); co-author with Anita Duncan Elizabeth Laton, *New Directions in Science,* McGraw-Hill Book Company, 1949; Co-author with Ruth M. Johnson; *Workbook in Chemistry,* Allyn and Bacon, 1931; Standardized Tests: *Powers General Science Test,* Forms A and B, 1927, Bureau of Publications; co-author with O. E. Underhill *Cooperative General Science Tests,* Five Forms, 1933, Cooperative Test Service; (co-author with F. L. Fitzpatrick) *Cooperative Biology Tests,* Five Forms, 1933, Cooperative Test Service; (co-author with Mervin E. Oakes) *Oakes and Powers Test of General Biology,* Forms A and B, 1929, Bureau of Publications; *Powers General Chemistry Test,* Forms A and B, 1929, World Book Company; and the author of some 15 teacher guides.

The titles of Dr. Powers Master's Thesis and Doctor's Dissertation completed at the University of Minnesota in 1919 and 1923 respectively were: *History of the Teaching of Chemistry in the High Schools of the United States Previous to 1850* and *A Diagnostic Study of the Subject-Matter of High School Chemistry.*

Among many honors in addition to the above listed secretaryships, presidencies, and chairmanships, Dr. Powers has received are: Fellow in the AAAS; Listing in *Who's Who in America, Who's Who in the East and Northeast, Who's Who In Education, Leaders in Education,* and *American Men of Science.* One of the most prized honors was as Recipient of the Outstanding Achievement Award on the occasion of the Centennial of the University of Minnesota, College of Education, May 24, 1951.

Dr. Powers served as Editor of *Science Education* for a two-year period, 1944 and 1945.

It is difficult to adequately evaluate the many and varied contributions made to the general area of science education by Dr. Powers. No other person has exerted as

great an influence in this area during the last three decades, a period that has been so significant in promoting better science teaching implemented by numerous research studies. His influence has extended across not only the United States, but even around the world, both through his own efforts and those of his students, a number of whom have been from foreign countries.

Dr. Power's pronouncements and philosophy as presented in the Thirty-First Yearbook of the National Society for the Study of Education, in his numerous articles and committee reports, in numerous professional meetings, and in the standards of research required of his graduate students have had an incalculable influence on science teaching. Dr. Power's early work in studies of science vocabulary, standardized science tests, and in chemistry and science subject-matter were contributions of great significance. It is estimated that Dr. Powers has had some 5,000 students in his various classes at Teachers College and other colleges. More than sixty students completed doctoral studies in science education under his direction. Many of these individuals hold important educational posts around the world.

Dr. Powers is both an original worker and skilled at bringing the findings of others to their greatest fruition. To a large extent, he has devoted his life to science education research and the improvement of science teaching. His devotion to his work has been unequalled. What was said of Professor Eikenberry in the October issue can as appropriately be said of the professional interests, attitudes, and ideals of Professor Powers.

Dr. Powers had the gift, to a greater extent than most science education leaders, of stimulating his graduate students to sense a research problem and see it through to its fulfillment. Whatever contributions to science education that may have been made by this writer, small as they may well be judged, are due in most part to the patient guidance, suggestions, and stimulating influence of Professor Powers. For two years (1926–28) we had the high honor and privilege to serve as graduate assistant in his department at Teachers College, Columbia University. During his many years at Teachers College, Dr. Powers was recognized as having one of the keenest, most penetrating minds on the Teachers College Faculty. A dissertation of one of his graduate students, which he had approved or he had approved of as a member of a committee, was practically certain of being approved by the Committee on Higher Degrees. The writer was once assured by a person in an excellent position to judge, that "when Dr. Powers approves your dissertation, you need have no fear of the Committee on Higher Degrees. He is recognized as having one of the best research minds and as having the highest standards of research of any Teachers College Faculty member."

To the writer, it seems Dr. Powers was especially effective in his work with the individual student, absolutely impartial, and a keen analyzer of science education research problems. He had the rare ability to go to the heart of a problem and grasp the fundamentals of that problem. He approached science education problems with the objectivity ascribed to great scientists.

This recognition of Dr. Powers would be lacking in a most important aspect did we not make reference to the important contribution made by Mrs. Powers to Ralph's professional and social success. A more gracious hostess the writer and his wife have never met. Well do we remember the many Sunday afternoon teas and education meetings at which Mrs. Powers served as hostess.

When the advances made by science education in the first half of the Twentieth Century have been finally evaluated, it is most probable that no other name will excell that of Professor Samuel Ralph Powers. So to Professor Powers deservedly goes the Third Science Education Recognition Award.

Clarence M. Pruitt

ELLIS CLYDE PERSING

Mr. Ellis Clyde Persing, prominent educator and author in the field of natural science, and a well-known teacher in the Cleveland, Ohio, high schools and Western Reserve University, passed away April 4, 1956. Mr. Persing suffered a stroke on the way home from school in the afternoon of the day before.

Mr. Persing was born November 17, 1885 in Snydertown, Pennsylvania. He married Jennie Valeria Herb on December 27, 1911. She and a son Ellis C. Persing, Jr. survive. Also surviving are two brothers, Kimber M. Persing of Cleveland and John L. Persing of Shamokin, Pennsylvania. Mr. Persing had planned to retire from teaching in June, 1956.

Mr. Persing received an A.B. degree from Bucknell University in 1911 and an M.S. degree from the University of Chicago in 1926.

Teaching experience included five years in the rural schools in Pennsylvania, six years teaching biology, physics, chemistry, and general science in high school at Tyrone, Pennsylvania (1911–12), Cooperstown, North Dakota (1913–14), and Wellsville, New York (1915–17). Mr. Persing served five years as head of the science department in the Glenville High School of Cleveland and fifteen years as assistant professor of elementary science and biology in the School of Education, Western Reserve University, Cleveland. Since 1936 he had taught biology and photography at West Technical High School in Cleveland and had served as lecturer in science education at Western Reserve University. He served one year as assistant in the Natural Science Department, Teachers College, Columbia University. Mr. Persing conducted field trips in Yellowstone and Glacier National Parks (1931); Zion, Bryce, and Grand National Parks (1932 and 1933); Rainier, Pacific Northwest, and Alaska (1934).

Memberships in societies included: National Education Association, National Science Teachers Association, National Association of Biology Teachers, Ecological Society, National Parks Association, Photographic Society of America, Ohio Academy of Science, Central Association of Science and Mathematics Teachers, Phi Delta Kappa, National Council on Elementary Science, the Wilderness Society, American Nature Study Society, and the National Association for Research in Science Teaching. He was a charter member of the NARST. He served as Secretary-Treasurer of the National Council of Supervisors of Nature Study and Gardening. He served as President of the American Nature Study Society in 1933–34. He was President of the National Council of Supervisors of Elementary Science in 1931–32. He was founder and also first president of the Cleveland Natural Science Club and for many years served as executive vice-president.

Many will recall the numerous articles of Mr. Persing in *Normal Instructor and Primary Plans* (some 27 articles in this magazine) and some 20 other articles in *General Science Quarterly, Science Education, School Science and Mathematics, The Educational Screen, The Elementary School Journal, Journal of Chemical Education,* and *Leica.* He served as Editor of the Book of Knowledge Lesson Series (The Grolier Society); Editor: Science and Invention School Service; Editor of *The Classroom Guide* (The Grolier Society); *Experiments in Elementary Science* in Volume IX and also Volume IV of *Childcraft.* He edited a science education page in *American Forest and Forest Life* from 1929 through 1935. He was co-author (with K. M. Persing) of a *General Science Work Book* and co-author of *Elementary Science By Grades,* Books One, Two, and Three (with Elizabeth Peeples), Book

Four (with Edward E. Wildman); Book Five (with C. L. Thiele) and Book Six (with John Hollinger)—all published by D. Appleton and Company; *Laboratory Chemistry Test,* Forms A and B, 1929, Public School Publishing Company.

Major interests of Mr. Persing over a long period of years and continuing until his death were conservation education in elementary and secondary schools, and photography and color photography in the secondary schools.

Science education, and especially elementary science and conservation education, have lost a leader, an important contributor, a valued friend, and worker in the passing of Mr. Persing.

CLARENCE M. PRUITT

SYMPOSIUM: NEEDED RESEARCH IN SCIENCE EDUCATION

HERBERT A. SMITH, JACQUELINE BUCK MALLINSON, CLARENCE H. BOECK, HERMAN BRANSON, AND THOMAS P. FRASER *(Chairman)*

INTRODUCTION

THOMAS P. FRASER
Morgan State College, Baltimore, Maryland

THE papers presented during the symposium on "Needed Research in Science Education" at the Twenty-Ninth Annual Meeting of the National Association for Research in Science Teaching represented attempts by five well-known leaders in research in science teaching from among the membership of the NARST to examine the type of research that is needed in science education at the elementary, secondary, and college levels.

This initial look at the future research in science education represented the major project of the *Committee on Needed Research* during the year, 1955–56. The chairman of the committee was Thomas P. Fraser of Morgan State College who presided during the symposium session in Chicago.

The presentation on teacher education by Professor Guy Cahoon of Ohio State University did not reach the Committee in time for publication in this issue of *Science Education.* The summary presented by Professor Vaden Miles of Wayne State University is not included in the symposium manuscripts because it represented an overview of the major points developed in the several papers.

It is hoped that the manuscripts presented, as well as the discussions which followed, may be useful to research leaders in planning types of research needed to produce positive effects on everyday practice.

PANEL STATEMENT PRESENTED FOR SYMPOSIUM ON "NEEDED RESEARCH IN SCIENCE EDUCATION"

HERBERT A. SMITH
Director, Bureau of Educational Research and Service
University of Kansas, Lawrence, Kansas

DR. FRASER'S invitation to participate in this panel discussing "Needed Research in Science Education" was both an inspiration and a challenge. The NARST occupies a strategic position in science education and must meet some rather demanding responsibilities. This organization must provide leadership, inspiration, and chal-

lenge to those who are conducting, or those who would conduct research in science education, if it is to meet the responsibility which its strategic position provides. Thus, the challenge to "think big" should prove stimulating to us here in our 29th annual meeting. In a recent statement, U. S. Commissioner of Education Brownell, whose father, by the way, was a thoroughly dedicated science educator and a member of this Association, inferred that we are guilty of operating and thinking on much too limited a scale in many of our research endeavors. Perhaps this panel can accept the challenge and make a presentation for which such a criticism would be invalid, since we may discuss research without being fettered for the moment by operational, financial, or temporal considerations.

Perhaps my remarks should be prefaced by saying that I recognize that contributions have been made in areas to which I shall refer later in this paper. Nevertheless, I am sure that in most instances, at least, the investigators would admit that much remains to be done. Thus, without in the least intending to be critical of the work already accomplished, I hope to be able to point out that some further extension of work is needed. I would say that I am indebted to many other people, some of whom I will identify, for some of the ideas which I am about to present, and can therefore make no claim to a great deal of originality. Obviously, too, one cannot cover everything that needs to be done in science education in fifteen minutes; hence the ideas presented constitute a "sample" and not a "population."

SOME BASIC CONSIDERATIONS

A happy resolution has not been made of the dilemma of how to prepare the student destined for specialization in science as well as for the general needs of all students for science instruction. We are facing both an increasing demand for better training for the student who needs science as a pre-vocational subject and the equally insistent demands by school administrators and curriculum workers as to the needs of all students for science for the future citizen. These two objectives are somewhat divergent and we have not been able to weld them together into a state of harmonious compatibility. Perhaps of all academic areas in the curriculum the science area is most critical in this regard. Of course, the problem is most critical in the 55 per cent (1952 survey) of the high schools of the United States that enroll fewer than 200 students. But who can say that the large schools which have tried to achieve either one or the other of the objectives for each child have reached a really satisfactory solution to the problem? The future Ph.D. in pure science is also a citizen, and as a citizen has the same general needs. We are not unfamiliar with the complaint that even our Ph.D.'s are highly trained technicians. The basic question is, "How do we prepare for *both;* the needs of all people who are destined to live in a scientific and technological society and the needs of those few who are going to be the science specialists of tomorrow?" There is no choice. *We must do both.*

The second point is related to the fact that there is a genuinely competitive race for the competent individual. Once our society had need for whole battalions of "pick and shovel" men. Today that need is limited. Rather there is need for leadership and competence on a scale never seen before. The "thinking" man is in demand in government, in business, in industry, in the armed forces, and in the professions. It is obviously unrealistic to fill the needs in one area at the expense of another. We are not educating enough manpower to fill all of the demands in spite of the fact that a great reservoir of ability remains untapped. In terms of the ability of the average college graduate, approximately 40 per cent of the high school graduates with this relative brightness do not enter college, and 20 per cent who enter college, fail to graduate. Thus, in terms of this

ability level the attrition between high school graduation and college graduation is 60 per cent.[1]

A third point is really a question. Has life become really too easy for youth? Have the pleasant diversions of the swimming pool, athletic contests, and commercialized entertainment taken their toll? The road to scholarship is long and arduous and in these days material success is easily achieved without undertaking so difficult a journey. Speaking of the dark ages, Cubberly said, "Work largely ceased because there was no security for the results of labor." [2] In the present day is scholarship faltering because there are no unique rewards attached to scholarly attainment? At least there are none which adolescent value-concepts are likely to embrace on a large scale.

I am appalled by the low standards of discipline and scholarship in some schools, standards at least condoned by school administrators and teachers and supported, if not in fact, demanded by parents. Can such circumstances account for some of the antipathy toward science and mathematics?

MAINTAINING INTEREST OF CHILDREN IN SCIENCE

One of the fundamental questions that we must face is why students lose interest in science. We are all acquainted with the fact that in pre-school and lower primary grades children have a great many interests which might properly be termed scientific. They ask endless questions derived from their observations of their environment. These questions involve plants and animals, the stars and the sky; they involve the processes of reproduction and life and death itself. Why is it then that we see a gradual diminution of these interests as a child progresses through the school? Very frequently by the time the child gets to the junior high school years he seems to have no interests in science at all. Is this due to the development of competing interests? Is it due to poor teaching? Is it due to maturation or to the development of an anti-scientific set of values during adolescence? Just exactly what are the factors that contribute to this frequently observed phenomenon? A related point has been mentioned by Dr. Clarence Boeck in the Third Annual Review of Research in Science Education, in which he points out that it is all very well to have studies of the present interests of children but what is needed now is some study of the effect of the curriculum itself as a determiner of interests.[3] It is inconceivable that we cannot educate the interests of children. It is just as logical and just as necessary to educate with regard to this characteristic as it is to educate for many others. It seems apparent that research directed toward identifying those curricular procedures, materials, and processes which nurture and develop new and enrich present interests of children, especially in the area of science, ought to be more extensively developed.

TEACHER TRAINING

The record of teacher training institutions in the training of teachers for science instruction is not bright. The generally unsatisfactory level of training is so self-evident that it is unnecessary to devote time to developing the details. Even large multi-purpose institutions with tremendous resources have not usually developed adequate programs. The plight of the prospective elementary teacher is desperate in many cases. She is faced with the unhappy prospect of choosing 6 to 10 hours in any one of a dozen or more highly specialized sciences which makes only the slightest contribution to improving her ability to teach science in elementary school. Nor do the programs provided for secondary teach-

[1] Wolfle, Dael. "Future Supply of Science and Mathematics," *The Science Teacher*, 20 (September, 1953) 160.

[2] Cubberly, Ellwood P. *The History of Education*. Houghton Mifflin Co., Boston, 1920, p. 116.

[3] Smith, Herbert A., *et al.* "Third Annual Review of Research in Science Teaching," *Science Education*, 39 (December, 1955) 355.

ers show much more coherence and practicality. The basic question is, "How can institutions develop better programs to prepare trainees for science teaching?" I should like to see some research at the college level devoted to this problem.

INHIBITING FACTORS FOR THE STUDY OF SCIENCE BY GIFTED CHILDREN

We need more investigation of the specific factors in school which inhibit the study of science among gifted children. Because of his greater intelligence the gifted child has more insight. Because of his insights, does he understand his associates better than they understand him? If this is true, does he have greater social sensitivity and, if so, is this likely to make him more conformist in regard to his relationship with his fellow students? Is poor teaching more detrimental to the gifted child than to his fellow students? Is it lack of challenge, or other factors that contribute to the making of science such an undesirable field of study for so many gifted students? Is science instruction in general, inferior to the instruction provided in other academic areas?

SOME NEEDED RESEARCH RELATED TO CERTAIN ADMINISTRATIVE PRACTICES

Administrators are harrassed by a multitude of problems and many petty details. They are not likely to give detailed consideration to certain areas which are of primary interest to science teachers, but which have administrative overtones. Thus, if research is to be done in order to explore certain administrative practices which may not be in the best interests of the science teacher it is quite likely that it will be done by science teachers and not by administrators. Hence, I should like to take this opportunity to explore some ideas pertaining to science teachers in relation to general administrative policy. Particularly, I would like to examine two "administrative postulates" which I believe are not without important implications for science teachers and which are not unrelated to the shortage of adequately qualified science teachers which exists in the public schools today. I would state these postulates as follows:

1. Classroom teachers should draw equal pay for equal training.
2. Merit pay is not administratively feasible.

It has always been an intriguing question to me as to why postulate one should apply universally to classroom teachers and not to administrative staff. Equally intriguing has been the question as to why coaches and music directors and certain other specialized staff have generally been exempted from an application of this postulate. In fact, one wonders if the whole complex maze of titles and specialized positions in the typical big city school is not, in part, a result of trying to circumvent postulate one, and still reward good work. The unfortunate aspect of this situation is that it usually results in removing people from classroom teaching. (Where they could not stay and be rewarded!)

However, assuming that these discrepancies may be satisfactorily explained, let us examine the postulate as it applies directly to typical classroom teachers including the science teacher. If there is any validity whatever in this postulate, then certain assumptions have been made which no where have I found explicitly stated. Thus, I thought today I might try to state the assumptions which underlie postulate number one. These are:

1. The length of time and study or degrees earned assures an equality of training.
2. The same inherent difficulty is experienced *in training* for any teaching position at any level.
3. The same inherent difficulty is experienced *in teaching* in all types of teaching positions.
4. The potentials and aptitudes required in prospective candidates are the same, or at least the qualities required are as abundant in the general population for one type of teaching position as for another.
5. Employment practices in teaching may depart significantly from practices in labor, business, and other professional fields.

6. Societal demands for persons with certain types of skills (in this case, competency in science) can be safely ignored.

I seriously doubt the validity of each of the assumptions stated. Hence, I reject the postulate. I am also convinced that operating as though everyone of these assumptions were true has contributed materially to the present very grave crisis in science education, particularly in the shortage of qualified science classroom teachers in a vast number of our schools. But these are only my opinions. My point is then, that I believe research must be undertaken which will demonstrate conclusively the truth or falsity of these and perhaps other assumptions. I think that science teachers are well qualified to show initiative in this matter, and further, if real justice were done, they would be the ones who would be likely to profit most materially. Science teachers have shown themselves competent to conduct research. Certainly, they have contributed markedly to the development of the field of audio-visual aids. I see no reason why they cannot also contribute markedly to the development of better and more just and equitable administrative practices.

My time is running out, hence I will content myself with one comment about postulate two which I stated above. I can do not better than to quote a remark of Dr. Morris Meister's in which he stated that although administrators proclaim that they are unable to define good teaching and thus could not justify merit increases in salary on the one hand, on the other, they knew perfectly well where to take a visitor in the school in order that he will gain the best possible impression of the instructional program of the school. Is it possible that administrators are unwilling to face up to the tremendous human relations problems involved in administering a merit pay program?

There is one other aspect which appears to be suitable for inquiry along several lines. I think that it is entirely possible that a science teacher should be placed on an eleven month appointment. With the growing emphasis on science projects and science fairs, school gardens, nature hikes and nature paths; with visits to industry and similar projects, it looks as though it might be possible for the science teacher to provide needed services for eleven months during the year. There are the further tasks of maintaining science equipment, ordering supplies, inventorying and curriculum development. Is this plan feasible? How can it be supported? Should federal aid contribute materially to this sort of a plan? Should there be state supervision? These and other questions would lend themselves to a type of research investigation.

Application of Findings in Related Fields

I have overheard Dr. Hubert Evans of Columbia University mention the fact that we sometimes attempt to do in science education that which has already been better done elsewhere. I am inclined to agree fully with this statement. It is probable that we may have been rather slow in taking the fruits of research in many other educational fields and applying them to our own particular problems in the field of science education. Recent developments in group dynamics including such items as the influence of democratic versus authoritarian atmospheres in the classroom obviously must be related to much of our work with demonstrations, project teaching, class discussion and laboratory. I know of no thorough investigation which has made any attempt to determine the influence of some of the findings in group dynamics research applied specifically to science classroom conditions. There is a large body of research on leadership; there are research investigations of attitude and interest formation; and there are a large number of new techniques for the study of group phenomena which might be more thoroughly exploited. It seems to me that we

need to investigate rather thoroughly what some other fields of inquiry may have to offer us in our specialties. Can we use effectively such techniques as role-playing, sociograms and projection?

SOME GENERAL CONSIDERATIONS

There has been a considerable body of research devoted to the scientific method *per se* and also to scientific attitude. These studies have concerned themselves in the main with identifying various characteristics of persons possessing scientific attitudes or various evidences of the extent to which people possess scientific attitudes. Sometimes paper and pencil tests have been made to determine whether people have acquired skill in application of the scientific method, or to determine whether or not they have become more scientific in their outlook. We have not, however, really taken the last and crucial step. (Remember, this presentation assumes freedom from temporal, financial and operational restraints.) We have not made any long-range investigations of what this has meant in the actual behavior of the individual. Where are our observational records? Where are our longitudinal studies and our anecdotal records? Where are our chapters on the "content analysis" of the life of the individual? To what extent do we really know whether or not participation in science classes of any kind contributes to the making of a more scientific citizen, except perhaps in a narrow speciality? I personally feel that the evidence is all but completely lacking. Kenneth Anderson,[4] in an article in 1950, indicated that a rather clear-cut body of objectives had been formulated for science instruction, but that little effort to evaluate progress in achieving them even in the immediate classroom situation was evident. Where is the evidence that we have evaluated their contribution on the broader field of post-school life? The ultimate criterion of the effectiveness of instruction, and the real value of the objectives of instruction, rests in the behavior of the individual, not only today in the classroom, but tomorrow in the great world in which he finds himself. The comments of Dr. Frank N. Freeman in the appendix of the 31st Yearbook relative to transfer are pertinent here. We need effective research to demonstrate whether or not we really are teaching above the technician level. Are we really accomplishing the teaching of science at a reflective level of learning? It should probably be pointed out that the hue and cry at the present moment about the shortages of scientifically trained personnel is concerned almost entirely with a "technician" rather than a "scientifically-minded" citizen concept.

More synthetic studies are needed to do for us in the field of attitude development, interest development, and teaching of scientific method, what the great studies of Martin and Wise did to identify the principles of science of significance to general education. Interinstitutional and interdepartmental research involving experimental programs for the training of science teachers is another neglected area.

Perhaps these specifics will outline some of the ideas that I have which are related to needed research in science education. Here are perhaps, a couple of ideas that might be worth discussion. Is it possible that we might follow the AERA idea and develop some materials such as "What Research Says to the Science Teacher about the Teaching of Scientific Attitudes, or the Scientific Method, or the Development of Interest in Science?" These might be suitable NARST projects.

SUMMARY

I think my remarks have implied certain things. They imply more money for research, possibly outside foundation financing. Perhaps some money could be made

[4] Anderson, Kenneth E. "A Frontal Attack on the Basic Problem in Evaluation: The Achievement of the Objective of Instruction in Specific Areas," *Journal of Experimental Education,* 18 (March, 1950) 163–174.

available to NARST itself. I think it is obvious too, that we need a team approach to many of these problems. Maximal progress and development today will depend on our abilities to extract from the increasingly distal areas of specialization in education that which is significant for science education. Individuals will not do this alone; thus, the day of cooperative research in science education is at hand. Individual contributions will still be necessary, but much that needs to be done requires finances, skills and techniques which the resources of one institution and the repertoire of abilities or competencies of single individuals are unlikely to encompass. I think there are certain other things that we need to consider also. It is not improbable that we may find fewer graduate students contributing studies of significance to science education. It is possible that faculty contributions may be in for a decline because of the fact that their teaching loads and their other general university responsibilities are likely to be increased. Thus, we face some real problems. But, if we had no problems, NARST would have no reason for existing.

WHAT RESEARCH IN SCIENCE EDUCATION IS NEEDED TO STRENGTHEN THE ELEMENTARY-SCHOOL SCIENCE PROGRAM?

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INTRODUCTION

IT is obvious that any attempt to determine the type of research that is needed in elementary-school science education should be preceded by a study of the type of research carried out previously. Hence, this paper will briefly review the major research findings of recent elementary-science studies, as outlined in an earlier paper;[1] and will then suggest some areas fruitful for further investigation.

For convenience, the proposals will be categorized under four major headings: (1) The Purposes of Elementary Science Instruction; (2) The Methods of Teaching Elementary Science; (3) Evaluation in Elementary Science; and (4) The Training of Elementary Science Teachers.

THE PURPOSES OF ELEMENTARY SCIENCE INSTRUCTION

Within the past few years a vast number of research investigations have been undertaken in the field of elementary-school science education, a great proportion of which have been "status" studies. These studies have attempted to determine such factors as the scope of elementary science, the topics and principles commonly taught; and grade placement of such topics and principles. All these studies seem to point to the fact that the nature and importance of elementary-school science is now well-established. In addition, there appears to be general agreement with respect to the areas most commonly taught.

Unfortunately, however, these studies fail to show that elementary science educators have come to a common agreement with respect to the purposes of science instruction. In other areas of instruction, such as mathematics and communications, educators are agreed that the instruction should develop in the child certain specific skills and abilities. For example, elementary-school teachers agree that at the end of six years of instruction in arithmetic, boys and girls should be able to add, subtract, multiply, divide, etc. At the end of six years of instruction in communications

[1] Mallinson, Jacqueline Buck. "What Have Been the Major Emphases in Research in Elementary Science During the Past Five Years?," *Science Education*, XL (April 1956), 206–208.

they should be able to read, write and speak with a certain degree of facility. In other words, instruction in these areas is designed to help children *do* something better.

In science, however, teachers will suggest that, as a result of science instruction, boys and girls should *know* something about rocks, trees, animals, stars, etc. But it would seem that science, like the other areas of elementary instruction, should be designed to help children *do* something better. Hence, it is suggested that research is needed to identify in simple words, understandable to the teacher, the things that science should help children *do* better. The academic pedagese of "skills in problem solving," "elements of scientific method" or "critical thinking" are too vague.

Once these skills are identified, science educators may then proceed to determine the science activities that will be helpful in developing the skills. Teachers of arithmetic do not expect children to work *every* possible problem; nor do they expect them to remember the *exact* combinations of numbers they have experienced. Rather, the problem is considered to be merely a vehicle for developing the desired skill. Likewise, teachers of reading do not expect children to read *every* available book, nor remember the *exact* words appearing in the books they do read. Again, these devices are simply aids in developing a skill. By the same token, elementary-school children should not be expected to study *every* area of science or remember *every* science fact they study. There needs to be some major research on identifying "doing" activities that will help a child "do science" better on the basis of the skills described above.

THE METHODS OF TEACHING ELEMENTARY SCIENCE

Another area of elementary science that has been the subject of much research is that of methods of enriching the curriculum. A large number of studies have been carried out in an attempt to determine the relative merits of using such techniques as various audio-visual aids; community resources; and field trips. All these studies seem to point to the fact that, if properly used, most any teaching device is effective; and probably the use of a variety of methods is most effective.

Hence, in the future it would seem that researchers should concentrate their efforts on determining *how* any given method may be used most effectively. For example, some research might be conducted to determine how science films and filmstrips may be used to best advantage in order to help a child *"do"* more effectively; how demonstrations may be conducted to help the child develop specific skills, such as the ability to observe; and how field trips may be used to help a child learn to report accurately his observations.

The problem of lack of equipment and its relationship to teaching has also been the subject of much research. Studies show that the majority of elementary classrooms have little or no science equipment available. What they do have usually consists of discarded or borrowed high school science equipment. Unfortunately, many elementary teachers believe that a large supply of material and equipment is necessary to teach science effectively. Thus, it would seem that this is another area that needs further investigation. It is suggested that research is needed to develop an experimental program using simple, inexpensive equipment; one that does not involve the use of high school materials.

EVALUATION IN ELEMENTARY SCIENCE

The problem of evaluation has long been one of the big "question marks" in elementary science. There have been fewer studies dealing with evaluation at this level than is true for the secondary-school and college levels. This situation may be due partially to the fact that it is difficult to use the common paper-and-pencil measuring

devices with very young children. In addition, it may also be due in part to the fact pointed out earlier, namely, that as yet science educators have not agreed on the desirable outcomes of elementary-science instruction. Obviously, until the purposes of instruction are determined, it is impossible to evaluate the instruction.

Thus far the majority of the research studies in the area of evaluation have been concerned with the measurement of the retention of factual material by children. Several studies have attempted to compare various evaluative devices such as observational techniques and paper-and-pencil tests. As with the use of teaching methods, such studies indicate that most techniques have some value, if properly selected and utilized.

It is suggested that research needs to be directed toward the development of paper-and-pencil devices that will measure a child's ability to *do* science, not simply measure his retention of facts. Such evaluative devices would be similar to those now used to measure a child's ability to *do* arithmetic or reading. In addition, some research needs to be undertaken to determine the most effective ways of using informal evaluative techniques in science. For example, the observation of work habits and the analysis of children's question and comments as methods of evaluation need to be investigated more carefully.

THE TRAINING OF ELEMENTARY SCIENCE TEACHERS

Since the teacher is basic to all instruction, the backgrounds and training of teachers have been popular topics for research in recent years. Unfortunately, however, this research has been of a negative nature. The vast majority of the studies in this field point to the discouraging fact that most elementary-school teachers have had little or no training in science; the training they do possess is of of little value in their work with elementary-school children; and, as a result of their lack of training, they "shy away" from teaching science.

Since the above facts are now well-established, it would seem that future studies should take a more positive view and focus attention on the things that can be done to alleviate the existing situations. For example, it might be well to investigate the content of survey courses in physical and biological science that will be of greatest value to prospective elementary-school science teachers, and to determine when they may best be offered in college. Also, attention needs to be given to the problem of in-service training for teachers now in the field. For example, what types of workshops are most helpful to in-service teachers; what types of supplementary aids are available from industry for the aid of teachers and how may they be used most effectively? Future research here needs to be designed to *help* the teachers, rather than condemning them.

SUMMARY

To summarize briefly, it is suggested that in the future research in elementary-school science education be more positive in nature. In the past, research findings have pointed out the negative characteristics of elementary science. They indicate that the subject is *not* taught effectively in most schools; that proper evaluation devices are lacking; and that most teachers are poorly trained to teach science. In the future it would seem that researchers might well direct their efforts toward identifying the specific purposes of elementary-science instruction; determining the methods of teaching that will be most effective in developing in children the desired skills and abilities unique to science; developing evaluative techniques that will measure accurately the outcomes of science instruction; and developing programs of pre- and in-service training that will be of value in preparing elementary-school teachers to teach science effectively.

WHAT RESEARCH IN SCIENCE EDUCATION IS NEEDED TO STRENGTHEN THE SECONDARY SCHOOL SCIENCE PROGRAM?

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SCIENCE education at the secondary school level, in spite of a broad and in some respects strong background of research upon which the methods of instruction and content to be taught may be based, cannot be considered to be a static field. In fact, few teachers or researchers in science education would admit to having *the answer* to the question, "How can science be taught most effectively and efficiently?" It will not be my purpose here to define exactly or completely all the needed research but rather to suggest areas and types of research which might be undertaken with profit for all science teachers.

Reviews of research would seem to indicate that the principles of science to be included in courses of study, especially the courses now considered to be the basic high school offerings, are at least reasonably well established. It may also be stated that the objectives of science instruction are generally accepted. These facts must not be construed to mean, however, that course of study and teaching materials research studies are not still desirable. This will be brought out in the statements immediately following.

We have had a pattern of junior high school science, general science, for many years. This program has shown steady growth and acceptance because the development of the program was based on sound assumptions and recognized needs. There are now, however, certain trends making themselves felt which need examination for possible bases of curriculum change. Among these trends is increased and improved instruction in science at the elementary school level and the assumption of certain content and objectives from the junior high school program by the elementary schools. This statement pertains especially to the objective concerned with the use of basic content for purposes of exploration of the science field arousing interest in science. There has resulted a number of problems in duplication of effort and repetition of content. Because there is reason to assume that the holding power of the high schools will continue to increase, the need for a truly terminal course in the junior high school will decrease. The following questions require answers: Has the presence of a possible terminal course in science suggested to too many pupils, their parents and advisors, the notion that additional enrollment and training in science is neither desirable nor necessary? Have certain areas of science, especially the earth sciences, been neglected in coverage? How well do generalized and/or integrated courses in the junior high school program provide the opportunities and challenges so essential for the early identification of prospective scientists? Is there any support for the hypothesis that the generalized and repetitive nature of the general science program may be a destroyer instead of a builder of interest in science? The problems suggested involve the institution and subsequent evaluation of new programs in junior high school science against the present programs.

There is a strong need for research pointed toward the development of reading materials in science which will cover the same principles and applications at several reading levels. There has been a good deal of research study devoted to the determination of the reading difficulty of science textbooks. This has resulted in the finding that many reading materials are inaccurately placed in terms of the grade for which they were intended. It is not now possible to give reading assignments covering the same content to pupils of varied reading ability because materials

of varying difficulty are not available. This is to say that general science texts are not adapted to use in biology, chemistry, or physics courses and the books for one level of general science do not satisfactorily supply reading materials for another.

Interest studies have been made over a period of many years with the hope that the results would allow for the establishment of science courses which would be more effective and palatable. The fact that most of the results indicated that the identified interests were transitory may suggest that interests can be taught. Because a high degree of interest is necessary for effective teaching and for the production of future scientists, a new approach to interest studies, research into the potentialities of the curriculum and teaching methods as broadeners and developers of interest, must be explored.

Evaluation of teaching and achievement in science may still be characterized as being centered on measurement of acquired factual information. Unfortunately this trend is continuing in spite of our knowing that this type of outcome is short-lived at best and of less lasting value than some of the other accepted objectives of science instruction irrespective of the future plans of the pupils. Examination techniques and tests themselves to measure achievement in these objectives including: the ability to use the methods of science, do reflective thinking, use problem solving techniques, and the degree to which the scientific attitudes were developed and employed by pupils needing development, validation, and standardization.

Any and all carefully designed and controlled studies of classroom techniques are to be welcomed. In fact, we have had far too few of them. Whether or not a definite superiority of one technique over another can be established is not necessarily the point since the results, in any case, will provide a greater pool of tested approaches to classroom methodology, content choice and organization of teaching materials. This will be especially true of any research concerned with the development of attitudes and problem solving ability. Many of the previously conducted studies should be repeated using the more effective designs and statistical techniques now available. A case in point would be the question of demonstration vs. individual laboratory work in the sciences. None of the presently available studies can be assumed to be definitive. Most of the conclusions were assumed without the use of adequate tests of significance, the results cannot be grouped together to provide a synthesized general statement of facts for the studies were not comparable in purpose, method or results. It would be interesting to study the relative merits of demonstrations and individual experiments when both were preceded by class planning with the purpose of the teaching to be the solution of a problem through the gathering of data from concrete experiences. It would be most useful to know the relative efficiencies of demonstrations presented at the most appropriate time in relationship to other class activities, and individual experiments which may be quite inappropriately placed in time because they must be rotated among the pupils over a considerable number of days. This is reasonably typical of physics laboratory experimentation when multiple pieces of equipment are unavailable. Should not such experimentation with teaching devices and techniques also be extended with demonstrations being compared with motion pictures of the same demonstrations? I do not know that exactly this has been done, although previous studies have compared demonstrations with any film which was available on the same topic yet not necessarily the very same materials.

Especially appropriate now, would be studies to determine to what extent, if any, a *general education* emphasis in science teaching at the senior high school level serves as an aid or deterent to satisfactory progress in college science courses and the

choice of pure or applied science as a career. It should not be inferred that the *general education* approach means only the teaching of fused or general physical or biological science courses, for it should also include this point of view in terms of the content and methodology in the so-called traditional courses of chemistry and physics.

An evaluation of the direct use and cooperative thinking of industrial and pure scientists as well as possible uses of their facilities, in teaching high school science is necessary in pilot studies. This evaluation would include assessing their effectiveness in all the various ways in which their efforts and facilities might be used.

How can we identify the prospective scientist among our pupils early in his secondary school life? Of at least equal importance, once identified, how can we best help these young people? This problem is especially acute in the small schools of the nation, the schools least likely to have the best of teachers and most likely to have the most restricted curricular offerings.

Finally, there is a great need for experimentation to be carried out through large scale, cooperative studies. This will provide for wider and more representative samples of the nations schools. It will also make possible the tapping of the resources of the teacher who is neither equipped for nor capable of carrying on research by himself, but whose assistance is needed to carry out full scale educational studies. At present there is too little known about work being done by the teachers who are trying out new ideas. These persons need assistance in implementing their planning and evaluation. They need to become a part of a team attack on problems wherein the local teachers supply the classes and instruction but the specialized researcher assists with the design and analysis. Unless the design and analysis are of the best, the research effort is wasted. We cannot afford to believe that the individual teacher can truly identify their most effective teaching procedures through the use of hunches and subjective guesses. We should instead begin to implement the notion that science teachers are sufficiently scientific as to want to solve their own teaching problems through the use of such methods as they would attribute to the scientist working in his laboratory.

WHAT RESEARCH IN SCIENCE EDUCATION IS NEEDED TO STRENGTHEN THE COLLEGE SCIENCE PROGRAM?

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THE subject of this talk rests upon two major premises which should not remain inarticulate. The first is that research in science education should be a vibrant, fruitful activity on the college level affecting profoundly our course methods, procedures, and philosophy. The second is that there is need to strengthen the college science program. One can argue these positions interminably. The anticipated doubling of our college enrollment within the next 20 years and the existing serious shortage of scientists and engineers may be taken as sufficient justification for us to examine at least in a cursory manner some research aimed at the college science courses as effective agents for realizing the aims and objectives of our colleges in science instruction and in meeting the needs of the specialized and general student.*

* I have long held a bias, however, against the opinions of anyone who makes a pronouncement on the significance of research problems which the speaker is not himself impelled to undertake. It is quite legitimate for a member of this audience, for example, to think that if these problems are so important and significant why am I not actively engaged in their investigation. A possible reply is that having invested years in other series of problems, one cannot in good conscience release them, even though adjacent research areas may be inviting.

When we enter into this field, it is good to keep clearly in mind that we are leaving the relatively simple environment, logically speaking, of amoebas, of rats, of carbon atoms, or of atomic nuclei for a really tough problem area of the applied social sciences where we encounter situations influenced greatly by aptitudes, maturity, previous experiences, preparation, aims, and levels of aspiration. So that whatever conclusions are reached, they are inevitably colored by these implicit and often imponderable parameters which usually cannot be controlled as rigidly as we might wish. When a writer insists that he has achieved a measure of control over them, his arguments are rarely convincing.

It is essential in discussing this topic to give more than passing attention to the nature of our problem, for so often the results of a study in science education are unjustly depreciated, since almost any reader recalls a teacher who never used anything save the straight lecture system, yet he was able by the force of his personality or by example or by some combination of qualities to inspire his students to learn, to study, and to entwine his subject into their own lives to the extent that they felt that they needed and wanted to know the subject he was presenting.

This introductory statement is intended not as a pessimistic hazard but as an essential element for good experimental design in this very difficult field. To an outsider, the number of problems in this area of science education on the college level is quite large and like so many other applied social science areas the answers or solutions are rigidly limited in time. The applicability may change with a shift in any of the many relevant factors. The disconcerting fact is that the methods one teacher finds effective may be unproductive in the hands of another. In order to eliminate cautious statements in the discussion, I shall think of the needs of some hypothetical average class and some average teacher, avoiding the responsibility, except by implication, of defining this average.

On the college level the problem areas which seem to be most pressing in view of the present needs and expected increase in enrollment may be listed as:

I. Courses (Aims and Objectives).
- A. Classes
  1. Content (philosophical foundations, etc.).
  2. Lecture procedures (visual aids, demonstrations, etc.).
  3. Recitations and problems sessions (schedules, etc.).
  4. Examinations ("Testing for critical thinking," frequency, types, etc.).
  5. Methods depending on class size.
- B. Laboratory
  1. Procedure (conventional or project).
  2. Choice of experiments.
  3. Students working singly, in pairs, or in fours.
  4. The laboratory report.

II. The Student
- A. The non-science major
  1. Aptitude.
  2. Maturity.
  3. Preparation.
  4. Aims.
  5. Achievement.
- B. The science major
  1. Aptitude.
  2. Maturity.
  3. Preparation.
  4. Aims.
  5. Achievement.
  6. Other.

This listing is neither exhaustive nor definitive. An examination of the annual reviews of research on science teaching in *Science Education* or articles in the *Journal of Chemical Education*, the *American Journal of Physics* and other journals will reveal other problems which may not even with charity be subsumed in this list.

This is an innocent enough list. Some of us as college teachers, if not forewarned, would express very dogmatic and difficult to test opinions on any of the items. As an example, consider under laboratory, IB3, how should the students work, singly, in pairs or in fours? In a brief informal survey among some college teachers the overwhelming choice was for the students to

work in pairs. But in one of the most carefully designed and executed experiments in science education pertaining to physics instruction, Kruglak and Goodwin,[1] working at the U. S. Naval Academy in an experiment involving 6 instructors, 18 laboratory classes and approximately 200 midshipmen, concluded:

1. Laboratory achievement in general physics, as defined by mean scores on multiple-choice and performance tests, is independent of the number of students working on an experiment (up to four).
2. Students working in quarters earn better average grades on laboratory reports written in the laboratory than students working singly or in pairs.

(These authors list "Implications for Further Research" growing out of this study which are highly informative.)

With the exception of a few research studies in physics, of which Kruglak and his associates have contributed several excellent ones, our major activity as physics teachers is talking about these topics rather than the formulation and carrying through of a responsible experimental plan. There is some justification for this attitude as some topics on the list are avowedly difficult to reach experimentally, probable course content is good example (IA1). On the other hand it is conceivable that the teacher with a carefully thought-through set of aims and objectives may execute a small experiment of his own as to what particular "blocks" he will choose and "gaps" he will leave. And, of course, the same situation exists with respect to the choice of experiments (IB2). In spite of such statements that a certain course is based upon a "coherent body of knowledge, methods and attitudes which are typical of science," there seems to be no easy method of deciding upon just what the elements in these categories should be. This is well illustrated by the present discussion on the required college physics course for engineers. There is a consensus that pruning of the average course is necessary in order to include more topics from modern physics, but there is far from agreement on just what is to be cut or what should be added.

If we look now closely at the laboratory, we find here, too, that a few convincing science education experiments would be very helpful. Professor Sanborn C. Brown at M.I.T. has stated, "None of the larger institutions has yet developed a system of laboratory instruction which it can unreservedly recommend." Even if we had such a system there would remain the question of determining whether it is also suited for the non-science major as well as for the science major. This question will be asked with regard to many studies on the topics listed ahead, for there seems to be a widespread belief that the specialist and non-specialist science students have different needs. J. K. Major [2] has observed:

> Attempts to transplant the traditional course in general physics, usually administered to captive audiences of premedical and other technical students to new and admittedly experimental programs in general education for liberal arts students have not been spectacularly successful, while other courses, deliberately simplified for the non-specialist, have been severely deprecated by many physicists as "watered down" and have failed to offer any significant intellectual challenge to the brighter student.

The type of procedural concern which we have been emphasizing may appear quite trivial when we attempt to give structure to the innocuous appearing category listed under "The Science Major" as "Other" (IIB6). For it is in this category that we have placed a group of difficult adjustment problems recently discussed by Professor Lawrence S. Kubie who underscored the need for socio-economic studies of scientists and psychoanalytic studies of a random sample with a view to gaining information on:

[1] Kruglak, Haym, and Goodwin, Ralph A. "Laboratory Achievement in Relation to the Number of Partners," *American Journal of Physics,* 23 (May, 1955) 257.

[2] Major, J. K. "Introductory Physics in a Program of Directed Studies," *American Journal of Physics,* 24 (January, 1956) 30.

a. The special stresses, both economic and psychological, which occur in the life of the young scientist
b. The great variety of conscious and unconscious forces whose interplay determines a young man's choice of scientific research as a career
c. The interplay of conscious and unconscious forces in his subsequent emotional and scientific maturation
d. How the special stresses which develop later in life react upon the earlier emotional forces which originally turned him towards science
e. How unconscious stresses influence the young investigator's general approach to scientific research and scientific controversy
f. How the unconscious symbolic significance of particular scientific problems and theories can distort the logic and the judgment even of men of exceptional ability.

Some of these questions may be deemed outside the scope of science education. One can hardly deny, however, that they are important in the preparation of our abler students for careers in science—an activity which is certainly considered pre-eminent in most college science programs.

The college teacher of science who is sensitive to his failures or limited success in eliciting the maximum or even optimum response from his classes would be greatly benefited by a group of carefully formulated and executed research studies on the topics we have mentioned in this talk. One often gets the impression in teaching that it is not that we do not know but that we know such "a lot that is not true" (Professor Frank Knight so characterized another group). With the limited talent available in science for all types of basic work, I am not overly sanguine that we can expect too much in the immediate future although the stimulus given by the Ford Foundation grant (total grant $500,000) to the colleges to study ways and means of handling, without serious deterioration in the quality of their programs, the anticipated increase in enrollment should result in some science education studies especially with respect to techniques of handling the large class more skillfully.

Lord Kelvin stated that:

> Science is bound by the everlasting law of honor to face fearlessly every problem that can fairly be presented to it.

There is no doubt that the problems in science education at the college level meet this criterion. The proper execution of such studies is a highly technical and complex issue but their success offers the only hope of enlarging in a deliberate, convincing manner the body of applicable procedures, methods, and understandings necessary for meaningful science teaching.

THE "GOLDEN RULE" IN RESEARCH

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IN a recent article in *Science Education* we find this statement by Kenneth E. Anderson:[1] "Actually, statistical analysis of data is only in order providing the researcher: (1) . . . (2) applies the 'Golden Rule' of statistics. This in essence means that consideration is given to statistical techniques early in the study, which is often a controlled experiment, *before the data have been gathered.*" (The italics are mine.)

The article just referred to is the only one that I have seen which emphasizes this important point in the logic of testing statistical hypotheses: the statistical techniques must be chosen *before* the data have been gathered. The purpose of the present article is to emphasize this point with two simple examples that may help the reader to acquire "psychological ownership" of the logic of the situation.

[1] Anderson, Kenneth E. "The Statistical Approach to Problems in Science Education," *Science Education*, 38:390 (December 1954).

In an experiment involving a statistical test of significance the situation might be as follows. There are two groups, randomly chosen, with respect to some crucial quality, one the experimental group and the other the control group. It is decided that the statistical hypothesis tested shall be that the difference in the means (taken with respect to the quality in question) of the two groups will be zero after the experiment (the *null hypothesis*). The experiment is then completed and a test of significance indicates whether it is better for us to accept or to reject the null hypothesis.

Now suppose we were to say, "Since we have these data, let's see what else is significantly different about the two groups." Is this proposal logically sound? Will subsequent use of the test of significance be logically valid? Before we return to this question, let us consider two examples in elementary probability theory.

Suppose that we flip a coin ten times in a row and note each time whether a head or a tail appears. Let the results be nine heads and one tail. Interesting results but nothing to surprise us. The chances are a little less than one in a hundred that such an event will happen. But it will happen! Consider these possible results: H H T H T T H T T H. Nothing out of the ordinary you may say, but as a matter of fact the theory of probability says that the chances of this particular result are one in over a thousand! You see, *some* result *must* turn up even though each result individually may be very improbable.

Again, the chances of a poker hand called a royal-flush turning up in one hand of play is about one in 650,000. But the chances of getting the following hand: the two of spades, the seven of hearts, the nine of hearts, the jack of diamonds, and the three of clubs; are one in about 2,600,000! But, you may say, "I am always getting *those* hands."

It is not often that a royal-flush turns up, but it does turn up. If I am in a game with you and if after getting a royal-flush I say that it wasn't luck it was my favorite rabbit's foot, you will insist that we perform the experiment again. This is because you know that sometimes royal-flushes do appear, and not by any cause but by chance. If, on the second try, where the rabbit's foot is actually recognized as being a part of the experimental condition, a royal-flush turns up you may offer me a large sum of money for that talisman.

Let us return to the question of logic which has been raised.

In an experiment, a random sample which is taken with respect to some particular experimental quality, is almost certainly not random with respect to the great many qualities represented in the individuals of the sample. Thus "warmed-over" data are almost bound to lead one astray. What are the chances of this? It is impossible to tell, since the experiment was designed with other things in mind (or perhaps with nothing in mind). If a situation is discovered *after* the data have been used for their purpose, it is probably not unique at all; but if it is predicted *before* the experiment, then it may be truly unique. Therefore, we believe that the logic of our test of significance has lost its force, because *some configuration of the extra-experimental qualities must always occur.* Results which are derived from "old" data may be useful in suggesting future experimental programs, but, logically, they are suspect.

"Too many studies, supposedly experimental in nature, are like corpses—all that one can do is hold a post-mortem examination. An experimental study should be carefully planned in advance under condition which will afford a secure basis for new additions to knowledge." [2]

[2] *Ibid*, p. 390.

A LOOK AHEAD IN SCIENCE TEACHING *

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THERE is an old saying that coming events cast their shadows before them. The changes which have and are taking place in the United States have placed countless new demands upon our schools. We have experienced exponential growth on the production line with respect to many commodities such as radio, television, and automobiles. What we learn from this is that each individual emerges from school into a world whose technological development and political and social organization differs considerably from that of the world into which he was born.

The implications of this are tremendous. The future welfare of any nation is dependent upon that segment of its population who is competent in *science,* and who among us gains this competency unless he has mastered the facts, principles, methods, and skills of the sciences to the extent that his appetite has been sufficiently whetted to the point that he will go further or in short do research, pure research *if you will.* Failure of the sciences to heed the events which cast their shadows before them can only produce a citizenry incapable of controlling or further mastering their physical environment.

A number of substantial road blocks appear at this point on the educational scene. They are all too familiar to you. Nevertheless, it has been my privilege and duty during the past two years or so to assume the role of the crystal-ball gazer and thus to anticipate the number of students to be expected in our elementary schools, secondary schools, and colleges in the State of Kansas in the years ahead. It has also been my duty to estimate the dollars needed to educate these future students and to point out possible new sources of revenue to produce the needed dollars. Suffice it to say that these are quantitative matters amenable to statistical treatment and projection yielding confidence intervals accurate enough to convince even the least observant that we have a quantitative educational problem of great magnitude on our hands. There is also a more subtle problem of greater import, namely that of quality instruction in all phases of education including the sciences. There seems to be a dearth of high school youngsters college bound who are interested in scientific careers per se. Most youngsters who express an interest in science while in high school, are bound for the professional schools such as engineering where application of existing scientific knowledge is the paramount goal. Worthy as these vocational goals may be, apparently the professional schools have through strong advertising lured many a capable youngster away from pure science and encouraged him to set his sights on substantial monetary goals.

In order to counteract this trend and to guarantee a supply of youngsters interested in science careers per se, it is probably mandatory that we redesign the high school curriculum in science in terms of the spectrum of ability found in the modern high school. This simply means a two-track system which will enable the gifted to pursue the sciences more deeply and more extensively than their contemporaries of less ability.

Let us look first at the group whose ability ranges from below normal to above normal or from educable to highly educable but not superior. Certainly these students need science as part of their personal equip-

* A paper read at the Twenty-Ninth Annual Meeting of the National Association for Research in Science Teaching in Chicago, April 21, 1956.

ment to live in a scientific age. These students should be required to take two years of science entitled Science I and Science II or "Man and the Biological World" and "Man and the Physical World," in the ninth and tenth grades. Conventional laboratory instruction would not exist but student-conducted and teacher-conducted demonstrations, together with realistic field trips, would constitute not less than two-fifths of the instructional time devoted to these two courses.

But what of the superior science student or those in the upper 15 per cent in terms of scientific ability? Since more and more science of a general science nature is being taught in the elementary school grades, the program should start with a solid conventional course in biology in the ninth grade, followed by physics and chemistry in the tenth and eleventh grades. Conventional laboratory instruction in these courses would not only be intensive but individual as well. At least 40 to 50 per cent of the total instructional time devoted to these subjects should be laboratory, conducted according to the inductive-deductive approach used by Boeck.[1] The twelfth year should be devoted to a senior science entitled "Seminar and Problems in Science" in which the superior students would carry out original investigations and exchange ideas relative to the progress of the separate investigations.

The two-track system described above should certainly provide the students of average scientific ability with the basis for intelligent living in a scientific age and extend or stretch the students of superior scientific ability well beyond the mediocre threshold now reached by them.

Johnson and Pruitt [2] have shown that the individual method in laboratory instruction produced wider variation in achievement with conventional groups of students in biology and chemistry than did the lecture-demonstration and group laboratory types of instruction. Would not the individual method with superior students produce even greater variation and a greater release of individual differences? The inference remains plausible until tested under modern methods of design and statistical techniques.

One might well raise the question as to how to select students for the superior group. The criteria for selection might be a battery of examinations administered at the end of the eighth grade or at the beginning of the ninth grade such as:

1. *Cooperative Science Test for Grades 7, 8, and 9.**
2. *Cooperative Mathematics Test for Grades 7, 8, and 9.**
3. *American Council on Education Psychological Examination for High School Students.**
4. *The Guilford-Shneidman-Zimmerman Interest Survey.**

The validity of these examinations or others together with cutting scores for selection purposes would need to be established over a four-year period or longer. Classification of students into the normal or superior group should not be rigid but flexible to permit reclassification of students from one group to the other as interest and achievement in science wanes or waxes.

One might accuse the writer of being idealistic and that this type of program might work in a large high school but what of the small high school of which there are many in the Midwest and in Kansas? Certainly the identification of the gifted science student is possible and with imaginative-flexible scheduling, individual laboratory periods could be found. In order for this plan to work, the science teacher in the small high school must be given time to plan for these students. This will be partially accomplished by less laboratory work for the less gifted. Here the superior students

[1] Boeck, Clarence H. "The Inductive-Deductive Compared to the Deductive-Descriptive Approach to Laboratory Instruction," *Journal of Experimental Education,* 19 (March, 1951) 247–253.

[2] See page 101 in "A Program for Teaching Science," *National Society for the Study of Education, Thirty-First Yearbook, Part I,* 1932.

* Tests 624, 370, 278, and 739 as described in Buros: *The Fourth Mental Measurements Yearbook.*

can do much of the demonstration work under the supervision of the teacher. Without a doubt, all students probably would be assigned to the same science class whether it be "Man and the Biological World" and "Man and the Physical World" or General Science and Biology. The resourceful well-trained teacher, however, can differentiate instruction for the two types of students, especially in terms of laboratory assignments.

In view of increasing enrollments and decreasing instructional space in terms of science facilities, I believe the plan has merit. It is my firm conviction that the time is at hand when the superior science student must be nurtured, in much the same manner as antibiotics are produced today, under ideal laboratory conditions. Until this is done, we will continue to lose the scientific race to other countries in terms of future scientific developments which must come about, not through applied science, but through pure research and science. Whether or not the plan I have proposed would do the job is open to conjecture. If we are skeptical, let us try it for a few years. If you are critical of the plan, propose a different one. Regardless, let us put more emphasis on the superior student of science and let us give him ample individual laboratory experiences to tap his intellectual and inventive capacities.

The author of this paper wishes to call attention to the following article: Eugene Youngert "Giving the Bright Student a Break," *The Atlantic* (June, 1956), 39–41. Also, a Kansas high school enrolling about 700 students is offering a sophomore mathematics course which covers both plain and solid geometry in one year. About 20 gifted students interested in mathematics are in the course. Enrollment is optional and students may transfer back to the regular geometry class or students in the regular geometry class may transfer to the special class if record and interest warrant it.

A LOOK BACKWARD IN SCIENCE TEACHING: A REPLY TO KENNETH E. ANDERSON

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On April 21, 1956 at the convention of the NARST a paper was read by Dr. Herbert A. Smith of the School of Education of the University of Kansas. It had been prepared for delivery at the meeting by Dr. Kenneth Anderson under the title "A Look Ahead in Science Teaching." Dr. Anderson's absence, however, made it impossible to discuss the paper or debate the points of view expressed in it. This writer therefore would like at this time the privilege of taking issue with a number of points in the paper as it was read by Dr. Smith. Such a privilege was implied by Anderson when he stated in his paper, "Whether or not the plan I have proposed would do the job is open to conjecture. If we are skeptical, let us try it for a few years. If you are critical of the plan, propose a different one." The writer rejects the idea of trying it, but will propose another plan.

The writer would agree with Anderson that some plan is needed to "enable the gifted to pursue the sciences more deeply and more extensively than their contemporaries of less ability." Yet, he is of the belief that Anderson's mode of implementation is most impractical and especially so for Anderson's own state of Kansas in which there are many small high schools. Indeed, it would be impossible to administer except in the largest of high schools, and it is most doubtful as to whether it could be done successfully there. Further, it would create an intellectual elite which is the antithesis of democracy in the modern high

school. Even then there is great doubt that such an elite could be identified with the precision that Anderson implies.

First, although it is so implied, the plan is not new. It is as old as the hills—one program for the gifted (assumed to be college-bound) and another for those not so well endowed with intellect (the non-college bound). The dichotomy suggested by Anderson would be most difficult to draw. Who would make the "borderline decisions?" The validity of most of the tests that Anderson suggests for identifying the gifted would make them useful for little more than good estimates. Hence there would be many borderline decisions to make. The dual-track idea suggested by Anderson was one used in England for years and recently abolished since it became necessary at the end of the eighth grade to brand the student by means of tests as gifted or otherwise. The lack of success in so branding students was great. Certainly the findings of psychological research would negate the idea that it can be done.

Now what about the program? Let us take for example a high school of 700 students which is large by comparison with most schools in the country. According to Anderson, 15 per cent of the students would be gifted. Statistical evidence would indicate that of the 700, about 220 would be freshman; about 190, sophomores; about 160, juniors; and about 130, seniors. This would mean, if the 15 per cent could be identified precisely, that there would be about 33 gifted freshman, 28 gifted sophomores, 24 gifted juniors, and 20 gifted seniors. Obviously the giftedness of all of them would not be oriented toward the sciences. Would Anderson then suggest that they be recategorized into their areas of giftness with special programs in the areas of their talents like the one he suggests for science? Or, does he suggest that, regardless of areas of giftness, they all be "rammed through" the special science curriculum? If the first choice is made the classes could be held in telephone booths. The lack of logic to the second choice is patently obvious.

The recommendations with respect to the type of laboratory program are rather confusing. Boeck's study to which Anderson referred was not carried out with gifted students but rather with a group in which there was a broad spectrum of ability. It showed that the inductive-deductive method of laboratory instruction (with this type of group) resulted in superior increments of achievement. Yet Anderson suggests that this "conventional laboratory instruction would not exist" with the broad spectrum group, but only with the gifted students. The application of Boeck's findings in this manner is rather startling! In addition, one would find it difficult indeed to locate research that would support Anderson's suggestions for "two-fifths of the instructional time" devoted to laboratory with the non-gifted group and "at least 40 to 50 per cent of the total instructional time" devoted to laboratory with the gifted. Why these figures? And why the "conventional laboratory" with the gifted group? Many have considered the "conventional laboratory" inadequate and indeed Anderson has criticized it in many of his papers. This suggestion smacks of the "fifty essential experiments for physics" found in an early yearbook devoted to that topic.

If Anderson's suggestion were followed, only the upper 15 per cent would receive the program for training scientists and technicians. Presumably only the scientifically-talented proportion would get the training. Does he mean that among the lower 85 per cent there are none who should be inspired to enter scientific careers, or to take the more rigorous courses? Are they doomed at the eighth-grade level to only "Man and the Biological World" and "Man and the Physical World" for their high-school science experiences? It is widely recognized that in this "lower group" there are many on whom our future scientific technology must depend.

One wonders also if even talented ninth-

graders and tenth-graders are sufficiently mature to take biology and chemistry at the rigorous level that Anderson suggests and profit from them as much as may be desirable. May these courses not better be deferred two years until the students are more mature?

It seems to the writer that there seems to be much "arm-chair philosophy" in the recommendations suggested by Anderson rather than a cognizance of the down-to-earth problems attending the education of students in the modern high-school. Perhaps this is most evident in Anderson's statement, "It is my firm conviction that the time it at hand when the superior science student must be nurtured in much the same manner as antibiotics are produced today under ideal laboratory conditions." This statement has many vague connotations but few practical implications. It reminds the writer of Leacock's Guido the Gimlet who put the horn to his lips and blew a mighty blast—but the horn wouldn't blow! There are overwhelming doubts in the mind of this writer that this horn will blow.

The writer agrees with Anderson when he states, ". . . let us put more emphasis on the superior student and let us give him ample individual laboratory experiences to tap his intellectual and inventive capacities." But let us do it also to those who are less than superior and from whom much of our scientific progress must come! Anderson's suggestions will only serve to reduce the numbers available, not increase them. It must be remembered that the points in this critique are based on a high school of 700 considerably larger than the vast number of those in the United States. In the smaller high school Anderson's suggestions are unthinkable. There are many other points that could be criticized but the writer will stop here.

Propose a different program? Yes! The writer recommends the one entitled, "A Proposed Curriculum Structure for Science Teaching in Michigan."[1] This was developed by dint of much effort of a state association of science teachers. In the opinion of the writer it is far more practicable than the one recommended by Anderson. It is "A Look Forward in Science Teaching."

[1] Michigan Science Teachers Association, "A Proposed Curriculum Structure for Science Teaching in Michigan," *Metropolitan Detroit Science Review*, XVI (May, 1956) 11-15.

CHANGES IN TEACHING FROM THE USE OF RESEARCH IN SCIENCE EDUCATION *

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Would the teaching of science in elementary and secondary schools be different and better if teachers were informed of research work in science education and if the teachers were able to apply the findings of research in science teaching to their everyday classroom situations? Since 1938 almost one thousand studies of research in the teaching of science were reviewed in the October 1942, October 1945, October 1948, October 1951 issues of *Review of Educational Research* and in the first three annual reviews of science education research which appeared in *Science Education* in the February 1954, December 1954, and December 1955 issues respectively.

The classroom teachers find it impossible to keep up with these latest developments along with all of their other duties and responsibilities. Many teachers who would

* Paper presented at the annual meeting of the *American Educational Research Association* on February 21, 1956, in Atlantic City, New Jersey.

like to inquire into the current recommendations of educational research find these reports too technical and too difficult to interpret and apply to their classroom teaching.

However, it is encouraging to note that many teachers in the elementary and secondary schools return to in-service courses and workshops which are sponsored by their school systems and colleges where some of the latest methods, curriculum materials and resources in science are made available. In some school systems, science consultants are employed to assist in curriculum planning and teaching. Perhaps one of the major areas needed by elementary school teachers is the learning and understanding of basic science and its relation to natural phenomena in our environment, its impact upon our daily living and how citizens can make better adjustments to their surroundings.

Let us examine some of the changes in teaching science in the elementary school as a result of research in science education. Although there are some indications that most of these changes are for the better, instruments and methods of evaluation still need to be developed in many areas. Not all or most of these changes have been adopted in any given school. Many of the elementary schools do use a number of the following practices:

1. The science program is planned very carefully by teachers and science consultants and utilization is made of pupil interests and experiences whenever feasible. The program is flexible with respect to schedules, content, and pupil experience. Research has shown that it is ineffective to offer a science program which is rigid in terms of the syllabus and allotted time. It is likewise undesirable to offer a science program which is not planned carefully and is merely introduced whenever the children or the teacher feel this need. (See reference 12.)
2. Research has shown that the emphasis in teaching science should be placed on arousing and using children's interests, provide opportunities for solving problems which are significant for daily living and teach those scientific principles that are related to the development of scientific attitudes and the use of scientific method. This is different from the approach of teaching only fact getting. (See references 39, 45, and 51.)
3. A caution is given to elementary school science teaching. It is not desirable to "water down" the content of junior high school and senior high school science courses for elementary school children. Instead, it is suggested that the science content for elementary school children be appropriate in terms of the objectives stated above in 2. (See 15.)
4. Science education specialists are almost unanimous in their belief that many areas of scientific knowledge should be introduced in the elementary school curriculum to replace the outmoded nature study program as the only means of teaching science. (See 23.)
5. Using marionettes and pupil actors, several interesting plays centering around science were used by 45 children in the fifth grade. This dramatic approach to teaching science developed more desirable traits and attitudes than the conventional approach to teaching. (See 21.)
6. Research has shown that selected science radio programs gave children a better grasp of factual information and understanding of scientific concepts. These radio broadcasts also made for a better shift in attitudes pertaining to conservation of wildlife and natural resources. (See 13, 31, and 32.)
7. Elementary school teachers need better training in the biological and physical sciences and a rich background in social studies if they are to direct elementary science experiences for children in helping them observe natural phenomena and formulate generalization in science. (See 5, 17, and 35.)
8. Encouraging trends in the teaching of science in the elementary schools are: (a) a greater amount of time allotted to science, (b) more science classrooms that are better equipped with laboratory and other equipment such as visual aids, supplementary reading materials, well written textbooks and the stress of problem solving activities in the curriculum. (See 42.)
9. If elementary school teachers are given teaching-aid kits (pamphlets, posters, charts, films, and other teaching aids, in addition to workshops, personal conferences, and demonstrations, they are able to teach nutrition to children with the view of actually improving their daily eating habits. It was also found that children's attitudes towards new foods also improved when nutrition was emphasized in the curriculum. (See 27.)
10. Through an effective use of sensory aids (posters, pictures, bulletin boards, newspapers, radio reports) and opportunities provided for experimentation such as: *what we did, what happened,* and *what we found out,* elementary school children developed the habit of formulating conclusions based on facts rather than jump at a conclusion or accept anything. (See 11.)
11. Very few elementary school teachers are

aware of such doctoral studies as "The Selection and Grade Placement of Physical Science Principles in the Elementary School Curriculum." Another study deals with the selection of content for a functional course in science that can help children understand many things that arouse their curiosity. Such information would assist teachers in improving the science program. (See 26 and 40.)

Many interesting changes occurred in the teaching of science in the secondary schools as a result of research in science education. However, many secondary school teachers are not familiar with these research studies and it is likely that many of these following practices are not done at various secondary schools. If junior and senior high school science teachers were informed of the findings of science education research, they may well change their teaching procedures:

1. Several investigations have shown that it is possible to teach general science with the view of developing scientific attitudes and removing superstitions that 9th grade pupils have, if science is taught directly for these objectives. (See 10, 20, 22, and 29.)
2. Achievement in general science may progress more from the pupil's methods of work than the relation to intelligence, reading ability, and background. Perhaps more time should be spent by teachers in observing how the individual pupil works and studies in class. (See 7.)
3. Achievement in general science may be increased through the use of a workbook provided that the group of students are of higher intelligence. (See 2.)
4. A general course in the physical sciences offered in the 11th or 12th year enabled pupils to know more facts at the end of the year in comparison with comparable pupils enrolled in a chemistry or physics course. In teaching high school physics, pupils will learn and understand more science if the pupils plan the laboratory studies of their own choice. (See 24, 33, and 38.)
5. When pupils read a pamphlet about the physical universe in the 11th or 12th grade, they gain more information and shift their opinions about misconceptions than pupils engaged in a discussion group. (See 30.)
6. High school students in chemistry and physics courses attain higher scores on factual tests rather than tests which measure the understanding of principles and their applications. The implications of these studies and findings from other studies indicate clearly that students must be taught directly for problem solving ability, understanding of scientific principles and their applications. (See 4, 25, 37, 41, and 46.)
7. Newspapers, magazines, supplementary books, radio programs, motion pictures, scouting, collecting, and other hobbies have a positive effect upon pupils gain in information and in their ability to interpret natural phenomena. (See 6, 8, and 28.)
8. Pupils who are members of high school science clubs excelled non-members in terms of scientific knowledge. (See 14.)
9. In 9th grade general science, mental ability and reading skill are very poor indications of a pupil's ability to make conclusions. Likewise, if pupils are to learn the ability to solve problems, they must be taught how to solve problems. The content should be organized around large units of experience based upon the needs and interests of pupils. (See 9 and 44.)
10. In selecting content for a physical science course, it is suggested that no one specialized area of science is more important than materials taken from other areas. Many areas from physics may contribute more towards general education than a relatively larger number of major generalizations from chemistry. Several principles of astronomy also make worthy contributions to the area of general education. (See 49.)
11. Favorable results were reported in a follow-up study of 225 students when a high school chemistry course offered community problems such as food supply, science in agriculture, and control of the water supply. (See 18.)
12. In the 8th and 9th grade general science classes, experimental studies show that discussion before and after the showing of science films produces a significant gain in immediate and delayed recall of subject matter in comparison with classes in which the films were shown with no discussion. Note taking during the showing of science films distracted from the learning of science principles. (See 19, 50.)
13. In the area of human relations, it was reported that significant changes can be produced in student attitudes when biology and social studies classes were brought together in comparison with separate classes. (See 43.)
14. Pupils in high school biology achieved greater scores in the ability to interpret data, in learning principles and facts of biology and in problem solving ability when the course was planned cooperatively by pupils and teacher. (See 47.)
15. In a survey of 390 high school science teachers in 207 schools, it was found that few of these teachers are familiar with standardized subject matter tests and many of them are not inclined to administer them. (See 34.)
16. In the decade 1940–1950 many scientific advances occurred. There were 346 applications found in physics and 50 in chemistry.

Very few of these applications were used in the teaching of physical science principles on the high school level. Several studies indicate that many high school science teachers are not certified as fully qualified by state departments of education and they do not keep up with the latest developments in science. Qualified science teachers also have difficulty in learning of new technological developments because of inadequate time, overcrowded classes, too much clerical and administrative work and inadequate library facilities. (See 1, 16, and 48.)

17. Junior high school science is highly significant in determining at which level high school seniors decide to specialize in science. Competent and qualified science teachers, encouragement by parents who provide suitable reading materials, pupil hobbies that are related to science, out of school science jobs, affected pupil interest and the decision to specialize in science. (See 36.)

If all of our science teachers in America were to put into practice most of the above mentioned findings and recommendations based upon educational research, we could expect a more economical, effective, and inspirational program of science offered to our youth.

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AN ANALYSIS AND CHECK LIST ON THE PROBLEM SOLVING OBJECTIVE

Science Teaching Service Circular *

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ACHIEVING THE PROBLEM SOLVING OBJECTIVE

Problem solving, or scientific thinking, is a widely accepted outcome of science teaching in schools over the country. In the past much attention has been given to this objective in science education literature and there appears to be an increasing interest in it at present.

Very little reliable evidence is available to indicate the extent to which the problem solving objective is provided for in day-to-day classroom activities. Still less evidence is available on the extent to which the objective is achieved with the young people who study science.

Among other difficulties in reaching the fullest attainment of the objective is the failure, on the part of many teachers, to recognize that problem solving behavior is a complex ability made up of elements which can be identified. Some of these elements are quite simple manipulative skills but many more are of a highly intellectual character.

Regardless of the category in which these skills fall, it is very important to recognize that they are developed by recurrent practice just as any skill is developed. Thus, if a teacher wishes to develop some manipulative skill related to problem solving, such as learning how to locate information in a library, the skill must first be taught thoroughly and then practiced until achieved. In a similar way, if the teacher wishes to develop the ability to analyze problems, or interpret evidence, the skills must first be taught and then the teacher must provide classroom situations, day after day, when the pupil will have to use them. There is no easy way of teaching children to use the abilities of problem solving other than by setting classroom situations which call for their repetitive use.

Some authorities have characterized the steps in problem solving as a complete act of thought. This has led many teachers to believe that the act of problem-solving thinking, beginning with the recognition of a problem and ending with a conclusion, must always be practiced in its complete cycle. This is not necessarily true. Scientists rarely ever use the method in its complete cycle. In fact, they are more likely to use it in other ways.

For example, it is quite possible, in fact even desirable, to use the science lesson of a given day for practicing whatever elements of the total problem-solving pattern it may best be directed toward. In the development of a topic the teacher may plan to do a demonstration on a given day. This demonstration might provide material especially useful for practicing, among other things, the ability to interpret data. It should be used fully for this purpose and the teacher should see to it that all aspects of data interpretation afforded by the demonstration are carefully identified, clearly understood, and thoroughly practiced by the class.

On another day the teacher might find that a laboratory exercise could provide opportunities for testing an hypothesis or evaluating assumptions. This experience should be used to yield whatever practice for these purposes it might possess. The important thing to remember is that almost every classroom situation can in some way contribute opportunities for pupils to practice certain elements of problem solving. The teacher must be alert to recognize these

* This article in mimeographed form is available free in limited quantities. Address the author.

opportunities and to make the fullest use of each one. This Service Bulletin provides an analysis of the attitudes of mind that accompany problem-solving behavior and also an analysis of each of the major elements in problem solving. Such an analysis is essential first to suggest guides for teachers in planning classroom situations that will call for the practice of essential skills and second, to provide a basis for developing tests to evaluate the degree to which the skills have been attained.

PROBLEM SOLVING BEHAVIORS *

I. Attitudes which can be developed through science teaching

The science program should develop the attitude which will modify the individual's behavior so that he:

A. Looks for the natural cause of things that happen
1. Does not believe in superstitions such as charms or signs of good or bad luck
2. Believes that occurrences which seem strange and mysterious can always be explained finally by natural cause
3. Believes that there is necessarily no connection between two events just because they occur at the same time

B. Is openminded toward work, opinions of others, and information related to his problem
1. Believes that truth never changes, but that his ideas of what is true may change as he gains better understanding of the truth
2. Bases his ideas upon the best evidence and not upon tradition alone
3. Revises his opinions and conclusions in light of additional reliable information
4. Listens to, observes, or reads evidence supporting ideas contrary to his personal opinions
5. Accepts no conclusion as final or ultimate

C. Bases opinions and conclusions on adequate evidence
1. Is slow to accept as facts any that are not supported by convincing proof
2. Bases his conclusions upon evidence obtained from a variety of dependable sources
3. Hunts for the most satisfactory explanation of observed phenomena that the evidence permits
4. Sticks to the facts and refrains from exaggeration
5. Does not permit his personal pride, bias, prejudice or ambition to pervert the truth
6. Does not make snap judgments or jump to conclusions

D. Evaluates techniques and procedures used, and information obtained
1. Uses a planned procedure in solving his problems
2. Uses the various techniques and procedures which may be applied in obtaining information
3. Adapts the various techniques and procedures to the problem at hand
4. Personally considers the information obtained and decides whether it relates to the problem
5. Judges whether the information is sound, sensible, and complete enough to allow a conclusion to be made
6. Selects the most recent, authoritative, and accurate information related to the problem

E. Is curious concerning the things he observes
1. Wants to know the "whys," "whats" and "hows" of observed phenomena
2. Is not satisfied with vague answers to his questions

II. Problem solving abilities which can be developed through science teaching

The science program should develop those abilities involved in problem solving which will modify the individual's behavior so that he:

A. Formulates significant problems
1. Senses situations involving personal and social problems
2. Recognizes specific problems in these situations
3. Isolates the single major idea in the problem
4. States the problem in question form
5. States the problem in definite and concise language

B. Analyzes problems
1. Picks out the key words of a problem statement
2. Defines key words as a means of getting a better understanding of the problem

C. Obtains information regarding a problem from a variety of sources
1. Recalls past experiences which bear upon his problem
2. Isolates elements common in experience and problem
3. Locates source materials

* This analysis was prepared by Dr. Darrell Barnard, Professor of Education and Head of the Department of Science Education, New York University, and Dr. Ellsworth Obourn, U. S. Office of Education.

a. Uses the various parts of a book
    (1) Uses key words in the problem statement for locating material in the index
    (2) Chooses proper sub-topics in the index
    (3) Uses alphabetized materials, cross references, the table of contents, the title page, the glossary, figures, pictures and diagrams, footnotes, topical headings, running headings, marginal headings, an appendix, a pronunciation list, and "see also" references
b. Uses materials other than textbooks such as: encyclopedias, popularly written books, handbooks, dictionaries, magazines, newspapers, pamphlets, catalogues, bulletins, films, apparatus, guide letters, numbers, signs, marks in locating information, bibliographies
c. Uses library facilities such as: the card index, the Readers' Guide, and the services of the librarian

4. Uses source materials
    a. Uses aids in comprehening material read
        (1) Finds main ideas in a paragraph
        (2) Uses reading signals
        (3) Formulates statements from reading
        (4) Phrases topics from sentences
        (5) Skims for main ideas
        (6) Learns meanings of words and phrases from context
        (7) Selects the printed material related to the problem
        (8) Cross-checks a book concerning the same topic
        (9) Recognizes both objective and opinionated evidence
        (10) Determines the main topic over several paragraphs
        (11) Takes notes
        (12) Arranges ideas in an organized manner
        (13) Makes outlines
    b. Interprets graphic material
        (1) Obtains information from different kinds of graphic material
        (2) Reads titles, column headings, legends and data recorded
        (3) Evaluates conclusions based upon the data recorded
        (4) Formulates the main ideas presented

5. Uses experimental procedures appropriate to the problem
    a. Devises experiments suitable to the solution of the problem
        (1) Selects the main factor in the experiment
        (2) Allows only one variable
        (3) Sets up a control for the experimental factor
    b. Carries out the details of the experiment
        (1) Identifies effects and determines causes
        (2) Tests the effects of the experimental factor under varying conditions
        (3) Performs the experiment for a sufficient length of time
        (4) Accurately determines and records quantitative and qualitative data
        (5) Develops a logical organization of recorded data
        (6) Generalizes upon the basis of organized data
    c. Manipulates the laboratory equipment needed in solving the problem
        (1) Selects kinds of equipment or materials that will aid in solving the problem
        (2) Manipulates equipment or material with an understanding of its function to the outcome of the experiment
        (3) Recognizes that equipment is only a means to the end results
        (4) Determines the relationship between observed actions or occurrences and the problem
        (5) Appraises scales and divisions of scales on measuring devices
        (6) Obtains correct values from measuring devices
        (7) Recognizes capacities or limitations of equipment
        (8) Returns equipment clean and in good condition
        (9) Avoids hazards and consequent personal accidents
        (10) Practices neatness and orderliness
        (11) Avoids waste in the use of materials
        (12) Exercises reasonable care of fragile or perishable equipment

6. Solves mathematical problems necessary in obtaining pertinent data
    a. Picks out the elements in a mathematical problem that can be used in its solution
    b. Sees relationships between these elements
    c. Uses essential formulae
    d. Performs fundamental operations as addition, subtraction, multiplication and division
    e. Uses the metric and English system of measurement
    f. Understands the mathematical terms used in these problems; i.e., square, proportion, area, volume, etc.

7. Makes observation suitable for solving the problem

a. Observes demonstrations
  (1) Devises suitable demonstrations
  (2) Selects materials and equipment needed in the demonstration
  (3) Identifies the important ideas demonstrated
b. Picks out the important ideas presented by pictures, slides, and motion pictures
c. Picks out the important ideas presented by models and exhibits
d. Uses the resources of the community for purposes of obtaining information pertinent to the problem
  (1) Locates conditions or situations in the community to observe
  (2) Picks out the essential ideas from such observation

8. Uses talks and interviews as sources of information
  a. Selects individuals who can contribute to the solution of the problem
  b. Makes suitable plans for the talk or interview
  c. Appropriately contacts the person who is to talk
  d. Selects the main ideas from the activity
  e. Properly acknowledges the courtesy of the individual interviewed

D. Organizes the data obtained
  1. Uses appropriate means for organizing data
    a. Constructs tables
    b. Constructs graphs
    c. Prepares summaries
    d. Makes outlines
    e. Constructs diagrams
    f. Uses photographs
    g. Uses suitable statistical procedures

E. Interprets organized data
  1. Selects the important ideas related to the problem
  2. Identifies the different relationships which may exist between the important ideas
  3. States these relationships as generalizations which may serve as hypotheses

F. Tests the hypotheses
  1. Checks proposed conclusion with authority
  2. Devises experimental procedures suitable for testing the hypotheses
  3. Rechecks data for errors in interpretation
  4. Applies hypothesis to the problem to determine its adequacy

G. Formulates a conclusion
  1. Accepts the most tenable of the tested hypotheses
  2. Uses this hypothesis as a basis for generalizing in terms of similar problem situations

An inventory of problem solving practices can be used by a teacher in making an appraisal of the extent to which he provides for the suggested items under the various elements in problem solving. By making a self analysis of practices in regard to this objective, a teacher should be able to locate his strengths and weaknesses. This would provide a reliable basis for improving classroom practice.

INVENTORY OF PROBLEM SOLVING PRACTICES

Directions: Check your response to each of the following items in the proper space at the right.*

A. *Sensing and Defining Problems:*
To what extent do you:
  1. help pupils sense situations involving personal and social problems?
  2. help pupils recognize specific problems in these situations?
  3. help pupils in isolating the single major idea of a problem?
  4. help pupils state problems as definite and concise questions?
  5. help pupils pick out and define the key words as a means of getting a better understanding of the problem?
  6. help pupils evaluate problems in terms of personal and social needs?
  7. help pupils to be aware of the exact meaning of word-groups and shades of meaning of words in problems involving the expression of ideas?
  8. present overview lessons to raise significant problems?
  9. permit pupils to discuss possible problems for study?
  10. encourage personal interviews about problems of individual interest?

B. *Collecting Evidence on Problems:*
To what extent do you:
  1. provide a wide variety of sources of information?
  2. help pupils develop skill in using reference sources?
  3. help pupils develop skill in note taking?
  4. help pupils develop skill in using reading aids in books?
  5. help pupils evaluate information pertinent to the problem?
  6. provide laboratory demonstrations for collecting evidence on a problem?
  7. provide controlled experiments for collecting evidence on a problem?
  8. help pupils develop skill in interviewing to secure evidence on a problem?
  9. provide for using the resources of the community in securing evidence on a problem?
  10. provide for using visual aids in securing evidence on a problem?

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* On original paper, in four columns, space was allotted for checking under one of the following categories: Often, Occasionally, Seldom, and Never.

11. evaluate the pupils' ability for collecting evidence on a problem as carefully as you evaluate their knowledge of facts?

C. *Organizing Evidence on Problems:*
To what extent do you:
1. help pupils develop skill in arranging data?
2. help pupils develop skill in making graphs of data?
3. help pupils make use of deductive reasoning in areas best suited?
4. provide opportunity for pupils to make summaries of data?
5. help pupils distinguish relevant from irrelevant data?
6. provide opportunity for pupils to make outlines of data?
7. evaluate the pupils' ability to organize evidence on a problem as carefully as you evaluate their knowledge of facts?

D. *Interpreting Evidence on Problems:*
To what extent do you:
1. help pupils select the important ideas related to the problem?
2. help pupils identify the different relationships which may exist between the important ideas?
3. help pupils see the consistencies and weaknesses in data?
4. help pupils state relationships as generalizations which may serve as hypotheses?
5. evaluate the pupils' ability for interpreting evidence as carefully as you evaluate their knowledge of facts?

E. *Selecting and Testing Hypotheses:*
To what extent do you:
1. help pupils judge the significance or pertinency of data for the immediate problem?
2. help pupils check hypotheses with recognized authorities?
3. help pupils make inferences from facts and observations?
4. help pupils devise controlled experiments suitable for testing hypotheses?
5. help pupils recognize and formulate assumptions basic to a given hypothesis?
6. help pupils recheck data for possible errors in interpretation?
7. evaluate the pupils' ability for selecting and testing hypotheses as carefully as you evaluate their knowledge of facts?

F. *Formulating Conclusions:*
To what extent do you:
1. help pupils formulate conclusions on the basis of tested evidence?
2. help pupils evaluate their conclusions in the light of the assumptions they set up for the problem?
3. help pupils apply their conclusions to new situations?
4. evaluate the pupils' ability to formulate conclusions as carefully as you evaluate their knowledge of facts?

WHAT SHOULD BE THE SUBJECT-MATTER COMPETENCY OF SCIENCE TEACHERS? *

NATHAN S. WASHTON, *Chairman*
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PAUL BRANDWEIN
Forest Hills High School, Forest Hills, New York

BRENDA LANSDOWN
Brooklyn College, Brooklyn, New York

WILLIAM GOINS, JR.
Brooklyn College, Brooklyn, New York

ABRAHAM RASKIN
Hunter College, New York, New York

HAROLD S. SPIELMAN *(Recorder)*
City College, New York, New York

THE chairman, Dr. Washton of Queens College opened the meeting by clarifying the questions to be considered by the group. He suggested that the consultants and the audience concentrate upon the two closely related problems of how much knowledge of subject matter the science teacher should be expected to possess, and how much knowledge does the teacher actually possess.

* Report of a panel discussion sponsored by the four municipal colleges of New York City: Brooklyn College, City College, Hunter College, and Queens College, February 25, 1955.

The first consultant, Dr. Brandwein of Forest Hills High School, expressed the opinion that the prospective science teacher should be familiar with the methods of obtaining information concerning how our civilization has progressed technically to the level at which it now stands. He should also be familiar with *all* of the methods employed by scientists, rather than relying solely upon the so-called "scientific method." He should possess a knowledge of what science has done to and for our world, how it has affected our culture, and the responsibilities and obligations of scientists.

The second consultant, Dr. Lansdown of Brooklyn College, discussed science teaching in the elementary schools. She pointed out that many elementary school teachers are afraid of science. She stated that it was an important function of elementary school science teaching to keep the child's curiosity alive. This curiosity is often killed by teachers who feel that they must provide the child with all the correct answers. Therefore the teacher of elementary science should learn how and when to withhold giving the answers and should learn instead to help the child to find out the answer through his own efforts.

The third consultant, Dr. Raskin of Hunter College, reported the results of a questionnaire survey dealing with the preparation of secondary school biology teachers and teachers of science in elementary schools. The findings indicated that those surveyed believed the prospective biology teacher should be prepared for teaching by taking traditional college biology subject matter courses with emphasis placed upon courses in Human Biology and Physiology. All of these courses would possess practically the same content as biology subject matter courses given to college students intending to specialize in biological research or medicine.

The science preparation for those intending to teach science in elementary schools should emphasize a "Nature of Science" approach based upon the study of the strategy and tactics of science recommended by Conant. The teacher should at the same time develop the ability to work with and manipulate the materials and instruments commonly found in the science laboratory. He should possess knowledge equivalent to high-school achievement in physics, chemistry, biology and earth science.

The last consultant, Dr. Goins of Brooklyn College stated that the principal criterion for selection of subject matter for the prospective science teacher should be based upon functional understanding. The prospective teacher should learn how to transfer and translate these understandings into the lives of the children he will teach. Dr. Goins suggested a teacher preparation program emphasizing the following three points:

1. Acquisition of science information and an understanding of the principles and history of science.
2. Acquisition of a good background of information in the areas of the humanities and social sciences.
3. Professional training in methods of translating this knowledge into action.

He suggested that the preparation of secondary school science teachers include basic courses in each of the major sciences, and intensive preparation in one of them. The preparation of teachers of elementary science would be similar, but would include fewer courses in science.

He suggested that the laboratory experiences of these prospective teachers should involve real problems whose solutions are not previously known to the student. In answer to a question from the audience, he described such a program carried out at Tennessee State University. At this institution there is a formal requirement that all students majoring in science education must carry on one research project. Dr. Goins listed some of these projects: "Maze Behavior of Goldfish," "Qualitative and Quantitative Analysis of Crab-Apple Sandstone," and "Infra-Red Spectra of Fatty Acids."

The consultant concluded his remarks by

stating that an important function of the preparation of the science teacher should be to imbue him with a strong desire to carry on research dealing with the problems of bridging the gap between the possession of knowledge of subject matter and teaching the same subject matter.

Dr. Landsdown described some stimulating problems which she had observed being employed by seventh and eighth grades. One involved a series of genetic experiments with rats, while the other involved making a date with a boy or girl on Mars, giving time and place. Dr. Raskin suggested that perhaps it would be better if problems were used in which the solution was known by the teacher, but not by the students.

Dr. Brandwein returned to the subject of teacher preparation by pointing out that there are certain things the science teacher must be able to do. Among them are the following:

He must be able to teach the subject assigned him.
He must get along with his students.
He must get along with his supervisors.
He must be able to stimulate those students possessing aptitude and ability to go into the field of science.
He must be prepared to help talented students to initiate advanced research projects.
He must therefore know one area well enough to guide these future scientists.

Dr. Brandwein also pointed out the fact that with the exception of a dedicated minority, most of our college graduates who possess ability in science are attracted to positions in industry or research rather than in education. Those who select science teaching are all too frequently the "second-raters." We therefore face the problem of making certain that these people do not fail to acquire certain basic information concerning science. He emphasized that it is important that the new science teacher should realize that his appointment to a teaching position does not mark the end of his period of being a learner, but that he is only beginning to study and learn about science and science teaching.

Dr. Fox of Queens College suggested that science teachers be prepared to relate science to the problems of actual living and to the problems of the community. She suggested that the science teacher be prepared to help talented students to advance far beyond the point where they now are.

Dr. Brandwein stated that the prospective science teacher needs to acquire certain basic skills which will enable him to enter a class with confidence in his ability to handle the types of questions children are likely to ask. In addition, teachers should learn how to ask questions, rather than how to answer them.

A member of the audience suggested that a committee of elementary school, secondary school and college science teachers be set up to promote articulation, to discuss the problems and interrelationship of science teaching at these various levels, and to work for the establishment of science laboratory facilities throughout the elementary school system. Dr. Washton asked those desiring to serve on such a committee to indicate their interest on a card. A meeting of this group will be called in the near future by Dr. Washton and Dr. Spielman of City College who will function as temporary secretaries. Dr. Washton then summarized some of the statements.

SUMMARY

The following is a list of the outstanding statements and suggestions advanced by the consultants and the audience.

1. The preparation of the secondary school science teacher should include basic courses in each of the major sciences and intensive preparation in one of them.
2. The preparation of the elementary school teacher should include a minimum of one term of each of the following: Physical Science, Biological Science, and Earth Science. His knowledge of science would be equivalent to high-school achievement in these areas.
3. The preparation of science teachers should give them skill in manipulating equipment and develop a feeling of competence and confidence.
4. The prospective science teacher must learn not only the basic principles and facts of

science, but should be familiar with the history and development of science, the methods of science, and the effects produced by scientific progress upon our civilization.

5. The prospective science teacher should be given more opportunities to handle and work with young people in order to develop confidence and competence. He must learn how to ask questions—rather than how to answer them.
6. The science teacher should learn how to introduce problems that are challenging and interesting to his students, and to relate science to the everyday problems of the students and of the community. He should learn how to make use of all available facilities and resources for aid in solving these problems.
7. The science teacher needs to learn how to stimulate and guide talented students, so that these students will desire to pursue careers in the areas of science.
8. A committee of science teachers from elementary schools, secondary schools and colleges should be set up to consider problems of science education of common interest to science teachers at all levels.

LECTURES VERSUS PROBLEM-SOLVING IN TEACHING ELEMENTARY SOIL SCIENCE *

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For many years the college instructor has used the lecture method primarily to develop in his pupil the ability to solve problems which he is likely to face in his vocation. The pupil's ability to solve problems has been measured by how well he can recall specific facts which he can presumably apply when confronted with a problem situation later in life.

It has been assumed generally that, in many situations, the discussion problem-solving method is superior. But little has been done to analyze it critically and thereby determine in what ways it surpasses, is equally effective or, conversely, is actually less effective than other forms of instruction.

An experiment was designed at Cornell to compare the lecture and problem-solving methods of teaching based on the hypothesis that the student's ability to solve agronomic problems could be developed more effectively by guiding the student in solving selected fundamental problems than by lecturing.

A beginning soil course (Agronomy 1) was used for the study. This course required 7 hours per week of the student's time, as follows:

3 one-hour lectures	3 hrs.
1 two-hour laboratory	2 hrs.
2 one-hour recitations	2 hrs.
	—
	7 hrs.

There were 6 recitation sections. The experiment was conducted in the recitation period. There were about 140 students involved in three lecture-method sections and three problem-solving sections.

Purpose of Study

The main purpose of this investigation was to determine whether more "effective learning" for the solution of agronomic problems could be achieved by problem-solving than from the lecture method of instruction. This was to be determined by

(a) measuring growth or increase in marks between pre-test and final test
(b) achievement as measured by marks secured in final test
(c) students under both methods of instruction rating their progress in achieving the course objectives on a prepared questionnaire

Not all the subject matter of the course was considered in the experiment although the two methods of instruction were continued throughout the semester. The subject matter which was included in the investigation was related to five major areas—

* Paper presented at Twenty-seventh Annual Meeting of the National Association for Research in Science Teaching, Hotel Sherman, Chicago, Illinois, March 30, 1954.

I. Soils and Water Conservation
II. Soil Formation and Classification
III. Soil pH and Liming
IV. Organic Soils
V. Soil Fertility Maintenance

The Lecture-Recitation Method

At the beginning of the course an introductory lecture presented an over-all-view of the course. The students were informed of the two different methods of instruction which were to be considered during the semester. The lecture-recitation method as used in this study consisted of formal lectures on the subject matter included in the units cited. Occasional illustrations were used on important concepts covered in the lectures. Students of this group were given a mimeograph containing a short dissertation on problem-solving and the steps which one must carry out in order to solve any problem scientifically, but no further reference was made to it.

Mention was also made of the proposed visit to a farm. All students in Agronomy 1 would have the opportunity of seeing the application of much of the material which would be presented during the recitations.

The important ideas of the lectures were outlined on the board as the lecturer proceeded. The recitations were presented by the instructor or by the graduate assistant. All films, slides and soil monoliths were interpreted by the instructor. Students were not encouraged to ask questions; any which they asked were answered directly.

Students were always kept informed of any references. They frequently commented on the pertinent references in the text used for the course.

After each field trip (one to a farm, the other to examine roadside cuts of exposed soil) each student was required to prepare a written report. The reports were to include a record of the important soil characteristics and soil management practices observed. Students were instructed to make recommendations, in a general way, as to soil management practices which could be modified. All reports were read by the instructor, checked for organization, accuracy and detail. These reports were returned to the students with a grade and written comments.

At the end of the course a questionnaire, which had been prepared containing the objectives of the course, was presented to the students to rate their achievement in these objectives.

The Problem-Solving Recitation

Students were informed of the two different methods of instruction.

Among this group of students emphasis was placed entirely on student participation in recognizing and solving agronomic problems scientifically.

Problem-solving in this study consisted of those procedures which were planned to encourage student participation in—

Identification—and stating a major problem
Analysis—of the problem so that the student might see how to solve it
Discrimination—or choice of action of alternatives for solution of the problem
Evaluation—testing each possible choice of action
Generalization—developing the ability to use principles, understandings and skills in new problem situations which have been acquired in solving previous problems

Identification

Each student was asked to identify and state what he considered the most important problem for the first unit. This took place after the first field trip to the farm. Several statements of the problem given by students were written on the board by the instructor. The reasons for identifying these particular problems were also written on the board. The class then organized the problems into major criteria which could later be used to evaluate statements of problems.

Analysis

After the identification and statement of the problem students were asked what should be the first step toward its solution. This led to the analysis of the problem and discussion of techniques for analyzing such problems.

The analysis of each problem was carried out in groups of about 5 students. It generally took about an hour of discussion in

groups. A report of each group's findings and the findings of the entire class for the analysis of each major unit problem followed. Reports for each problem were mineographed and given to the students who were told to use them as a guide to aid them in collecting and organizing information related to their problems.

A copy of the major problem, its analysis, a brief description of the farm visited (including a map of the fields and boundaries) were included on a mimeographed sheet and this sheet was given to each student in both the lecture and problem-solving recitations. References made available were also included on the mimeographed sheet. The students were told that they would find the references helpful in solving the problems.

The farm was not used as the basis of the unit on Soil Classification and Formation. In its place several soil profiles representative of a Great Soil Group (found in some regions of U. S. A.) were provided. Again the recitations were subdivided into groups of about 5 students. The students, in order to make most effective use of the soil, were asked to state the problem which they would be faced with. Analysis of the problem followed. The steps toward its solution were considered. By studying each profile and recording the findings the students classified the soil giving a statement of reasons for its best land use. Approximately fifteen minutes at the end of each recitation were devoted to the spokesman of each group who reported the findings of his group to the entire recitation group. Opportunity was given at this time for members to observe profiles and worksheets of other groups' members.

Discrimination

The mimeographed material, which was now the student's worksheets, was collected at the end of each recitation. Students were encouraged to ask questions about the different materials and, as a group, select those they felt would aid them in the solution of the problem.

The instructor asked the students to get the purpose clearly in mind before any demonstration took place. Questions asked by students were used to clarify their thinking. After the demonstration each group was asked to formulate a generalization which would express a relationship between the ideas and facts that were involved in the solution of the problem.

Generalizations

Students were required to prepare a written report of each field trip and a completed copy of the mimeographed material referred to earlier. For each of the problems identified, each student was asked to include in his report his statement of the problem, an analysis of it, a record of the information gathered, reasons for the selection of a particular soil management practice, and clearly formulated generalizations.

The generalization was formulated after *recognizing* the essential features in the solution of the problems and *isolating* these from incidental features of particular areas.

The instructor read each unit report, corrected errors, suggested improvements and assigned a grade.

EXAMPLE OF PROBLEM-SOLVING PROCEDURE

Identification

At the first recitation meeting after the farm field trip students in the problem-solving recitations were asked to identify what they would consider major agronomic problems on the farm. One student recognized low productivity due to acid soils. Thus, he stated his problem as: "Planning a liming program for the farm."

Analysis

In order to solve this recognized problem groups of 5 students set about listing subproblems which needed to be considered, such as:

1. What is the pH of the fields at present?
2. What pH goals should we attain for the crops we wish to grow?
3. What kind of lime?
4. What rate of liming?
5. When should we lime?
6. Why should we lime?

Discrimination and Evaluation

Often alternatives are possible. A wise choice of action is required. For instance, several kinds of lime are available. Selection of the kind of lime most suitable is made by the student and reasons for such a selection are given.

Generalization

After the solution of the major problem by systematic consideration of the sub-problems, as suggested above, a relationship is made of the facts and principles used in its solution. In this case such a relationship could read: liming an acid soil results in more favorable conditions for legume establishment due to a reduction in the toxic ions of Fe, Al, Mn, improved nitrification and phosphorus availability, etc.

Essential Features, considered in formulating this generalization, which would be of use as *transference* to another problem are:

1. Liming reduces Fe, Mn, and Al toxicity
2. Liming gives favorable response to legumes
3. Liming increases availability of some important plant nutrients

Irrelevant facts to the generalization are:

1. Improved drainage necessary for response to lime
2. Liming reduces "damping off" damage
3. Lime mixed in sub-soil is necessary for legume establishment

Common Elements

The elements common in both methods included (1) questionnaires administered to students, (2) references given to students, (3) instructor and assistants teaching the course, (4) written reports of the field trips, (5) instructors' objectives in both groups, and (6) general subject matter covered. This latter factor was checked by means of a tape-recorder which was used during the recitations. By this means both the subject matter covered and the teaching procedures could be constantly checked.

Tests and Questionnaire Used

Two types of tests were constructed. The tests concerning recall of specific information were of the objective type and were prepared from various items of previous tests which proved to be differentiating among students.

The tests on abilities in problem-solving covered (1) ability to recognize problems, (2) analyze problems, (3) discriminate useful information and (4) formulate generalizations. Part of the test items could be scored objectively but testing for generalization called for a short written answer.

Tests measuring specific recall and problem-solving ability respectively were evaluated by a group of qualified jurors before being submitted to students. The actual test was constructed only after careful checking by the jurors and the subsequent refining by the writer.

Three tests were given during the study. First, the pre-test given before teaching the first unit. This was the complete exam and consisted of questions measuring specific recall and ability to problem-solve. A second test containing some items of the pre-test was given about half-way through the semester. The questions included subject matter already dealt with. The final test was given on completion and all the remaining questions of the original pre-test were asked; hence, it contained both specific recall and problem-solving questions.

Scores on the subjective parts of the problem-solving tests were derived from the juror's opinions concerning the relative significance of the student's ability to formulate generalizations. The objective scores were obtained by giving a grade of 2 points for the correct response, 1 point off for an incorrect response, and zero for no response. The total mark possible on the specific recall was 50 and, for the problem-solving questions, also 50. Thus, the percentage scores or gains shown were obtained by multiplying the raw number by two. Not all the component parts of problem-solving questions were weighed the same. Thus, identification and discrimination of problem were each given 15 points and analysis and generalizations were each given 10 points.

Questionnaire

A questionnaire was prepared to enable students to self-evaluate their progress toward certain objectives in Agronomy I. Included in the objective-type questionnaire was:

(a) provision for the student to select a vocation he would be likely to enter after graduation
(b) a rating of the method of teaching preferred by the student
(c) a rating of student's achievement in the listed major objectives of Agronomy I

Students were given opportunity to indicate their achievement in attaining these objectives by writing an appropriate number 1–5 (very poor . . . very good) beside each objective. Students also indicated, in a prepared table, the part of the course (lecture, recitation or laboratory) which contributed most toward achieving each of the objectives.

In a similar manner students were given an opportunity to rate new objectives (if they differed from those of the instructor) and their degree of achievement in attaining them.

Method of Equating Groups

An examination of the students under each method of instruction in the various recitations showed them on the basis of

(a) college year
(b) major interest
(c) farm experience
(d) chemistry background
(e) reasons for taking agronomy
(f) University record
(g) performance in pre-test

For each method of instruction there was good distribution of students in the groups listed above. The performance mean on the pre-test was almost the same for both methods of instruction and the standard deviations were of similar magnitude.

Comparison of the results was made on the gain obtained by all students between the pre and post tests for the two outcomes—recall of specific information and problem-solving ability. Since the mean on the pre-test for both groups was similar, the achievement on the final test was compared as a basis for evaluating the two methods.

The results obtained in the questionnaire were computed on a percentage basis. Students could rate 1–5 (very poor . . . very good) on the questionnaire. Since the median for rating fell between 3 and 4 it was decided to consider 1, 2 and 3 on a category equivalent to *low rating* while 4 and 5 were considered a second category equivalent to *high rating*. In so doing, the results tended to underrate the students' rating since many students checked the middle point 3 on the continuum.

Findings

Both the pre-test and the post test (designed to measure recall of specific information and problem-solving ability) used in this study were graded in a similar way. There were 60 questions in the test, each objective question having 5–10 alternative answers. There were from 1–3 correct answers for each question. Two points were given for the correct response and one point was deducted for an incorrect response. The raw score, so obtained, was converted to percentage. Thus, the total marks gained by the student, that is, the difference between pre-test and post test, are percentage scores. A period of 15 weeks lapsed between the pre and post tests.

Table I shows the comparison of mean gains obtained on recall of specific information by students under the two methods of instruction.

The mean gain of 25.0 for the lecture method recitation was almost identical to that of 24.6 obtained by the problem-solving method recitation.

It is interesting to note that the range of increment gain for the lecture recitation was 1–72.6 while that of the problem-solving recitation was 1–72.4.

When comparing the lecture method with the problem-solving method, with respect to recall of facts, other investigators have obtained results which would confirm these findings. Weissman [1] compared the relative effectiveness of teaching biology upon achievement in the ability to interpret bio-

TABLE I

COMPARISON OF THE MEAN GAIN BETWEEN PRE AND POST TEST OF THE EQUATED CLASSES ON THE SPECIFIC INFORMATION TESTS

Recitation Class	Instructional Method	No. of Students	Pre-Post Test Mean Gain	Pre-Post Test Weighted Average
I	Lecture	25	28.8	
III	Lecture	22	23.4	25.0
V	Lecture	13	20.4	
		60		
II	Problem-solving	32	28.6	
IV	Problem-solving	23	22.6	24.6
VI	Problem-solving	25	21.2	
		80		

TABLE II

A COMPARISON OF THE PROBLEM-SOLVING AND LECTURE METHODS OF INSTRUCTION MADE ON THE COMPONENT PARTS OF THE TEST MEASURING PROBLEM-SOLVING ABILITY

Part of Test Measuring:	Average Score of Sections Given Problem Solving Method				Average Score of Sections Given Lecture Method			
	II	IV	VI	Weighted Average *	I	III	V	Weighted Average *
No. of pupils	32	23	25		25	22	13	
1. Recognition	10.6	13.2	8.4	10.8	10.0	9.6	9.8	9.6
2. Analysis	8.8	8.2	6.8	8.0	7.6	6.0	5.0	6.1
3. Discrimination	20.4	26.0	20.0	22.4	24.4	21.0	20.6	21.9
4. Generalization	8.6	8.6	6.8	8.2	6.0	5.0	7.6	6.1
Total Gain				49.4				43.7

* Weighted averages taken $\left[\frac{M}{1} = \frac{\Sigma X}{N}\right]$ since different number of students in each section.

TABLE III

STATISTICAL PROCEDURE IN THE DETERMINATION OF ANY SIGNIFICANCE BETWEEN GROUPS

	Problem-Solving Method	Lecture Method
Number of students	80	60
Total gain	3949.2	2625.0
Mean gain	49.4	43.7
Sum of deviations squared Σx^2	7046	4749

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\left[\frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2}\right]\left[\frac{N_1 - N_2}{N_1 N_2}\right]}}$$

$$t = \frac{49.4 - 43.7}{\sqrt{\frac{7046 + 4414}{80 + 60 - 2} \quad \frac{80 + 60}{80 \times 60}}}$$

$$t = \frac{5.7}{\sqrt{\frac{11,460}{138} \times \frac{140}{4800}}}$$

$$t = \frac{5.7}{\sqrt{\frac{1337}{552}}}$$

$$t = \frac{5.7}{1558} = 3.66$$

logical science. Emphasis in the experimental classes was based upon solving problems selected by students. The control courses were taught by customary methods. Students in the experimental group made as great or greater gains in learning facts and principles. Utilizing students taking the survey course in biological sciences at N.Y.U., Barnard [2] compared the relative effectiveness of the lecture demonstration method with the problem-solving method. The evidence obtained from tests covering recall of specific information shows no significant difference between gains obtained by students under the two methods of instruction. Table II presents the results obtained by the two groups of students in the test designated to measure problem-solving ability.

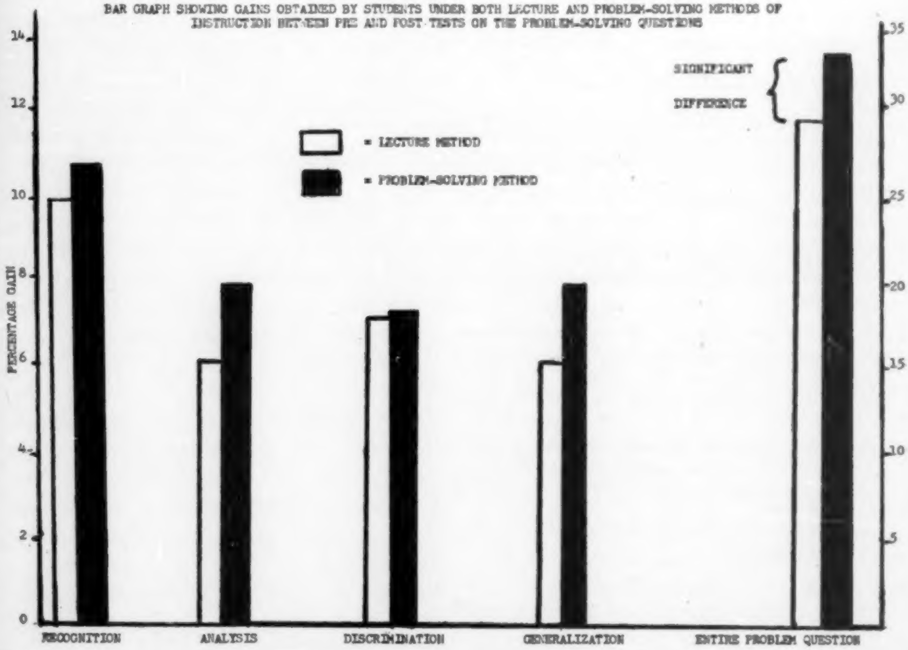
From Table III it may be seen that this difference of 5.7 between the two mean gains as shown by Fisher's t test was a significant gain since it was found to equal 3.66 with 138 degrees of freedom.

Thus, this mean increment of 5.7 between the grand mean of the lecture method recitation and the grand mean of the problem-solving recitation for the problem-solving questions was sufficiently large to assure that, in at least ninety-five chances out of one hundred, the differences would be significant.

Considering the totals recorded by each method of instruction, it is interesting to note in Table III that, in all the recognized steps of problem-solving, the students in the problem-solving groups were consistently higher than those in the lecture method recitations. The greatest difference between the groups appeared in the questions concerned with analysis of the problem and the formulation of a generalization. Two experiments are reported below which would confirm the findings of this investigation.

When comparing the problem-solving method with the lecture-demonstration method, Barnard [2] found that the students in the problem-solving classes made significantly greater gains than the lecture-

BAR GRAPH SHOWING GAINS OBTAINED BY STUDENTS UNDER BOTH LECTURE AND PROBLEM-SOLVING METHODS OF INSTRUCTION BETWEEN PRE AND POST TESTS ON THE PROBLEM-SOLVING QUESTIONS



demonstration students on the test designed to measure problem-solving ability. Tests on scientific attitudes also gave gains between pre and post tests significantly greater for the problem-solving students than the lecture-demonstration students.

Baar [3] conducted a critical analysis of selected literature dealing with methods of teaching science. The achievement of groups of general science students taught by the problem method was compared with the achievement of general science students in an equated group taught by a conventional textbook recitation and lecture-demonstration. Achievement was measured by objective tests administered before and at the end of the period of instruction. The problem method was found to realize better achievement in comprehension and interpretation of scientific problems.

Questionnaire Results

Table IV summarized the results of the students' rating of the questionnaire.

It would appear from Table IV that objectives 1 to 6 inclusive were rated significantly higher by the students in the problem-solving recitation than those in the lecture recitations.

In other words, students in the problem-solving recitations considered their achievement in reaching the above-mentioned objectives as greater than those in the lecture recitations.

A further analysis of the two groups was made in the questionnaire to indicate their vocational interest upon graduation. For convenience this has been considered as two major interests: (1) agronomic field workers; e.g., farmers, teachers, extension

TABLE IV

COMPARISON OF THE PROBLEM-SOLVING AND LECTURE METHODS OF INSTRUCTION IN RATING OBJECTIVES OF AGRONOMY I AS MEASURED BY STUDENT RATING

Instructors' Objectives	Per Cent Rating in Groups			
	L. M.		P. S.	
	Low	High	Low	High
1. To obtain an appreciation of the significance of soils and soil differences for successful agriculture and especially for crop production	58	42	42	58
2. To obtain an understanding of those fundamental chemical, physical and biological principles which ultimately determine practical utilization of soils	57	43	44	56
3. To relate those principles in 1 and 2 above to the practical production of crops	42	58	32	68
4. To develop the ability to evaluate soil fertility and productivity by examining and testing soils in the field	76	24	51	49
5. To develop the ability to recognize situations wherein soils are not being properly managed and to decide scientifically what should be done, to modify and improve the soil management practices done by				
a. Giving you the responsibility for making modification of soil management practices	33	67	26	74
b. Assisting you to evaluate current Agronomy practices	45	55	30	70
c. Assisting you to determine superior alternative practices	58	42	27	73
6. To guide you in acquiring and developing the social and physical skills which are essential for effective Agricultural leadership	65	35	41	59

TABLE V

COMPARISON OF THE PROBLEM-SOLVING AND LECTURE METHODS OF INSTRUCTION IN RATING OBJECTIVES OF AGRONOMY I AS MEASURED BY AGRONOMIC FIELD AND NON-FIELD WORKERS

Abbreviated Instructors' Objectives		Percentage Rating in Groups			
		L. M.		P. S.	
	Workers	Low	High	Low	High
1. Appreciation of soils and their differences in agriculture	field *	51	49	43	57
	non-field †	71	29	46	54
2. Understanding of the physical, chemical and biological principles related to soils	field	37	63	46	54
	non-field	78	22	27	73
3. Relate above principles to crop production	field	33	67	45	55
	non-field	55	45	28	72
4. Evaluation of fertility and productivity in the field	field	62	38	61	39
	non-field	66	34	67	33
5. Recognition of situations of poor soil management and decisions to modify them	field	52	48	28	72
	non-field	53	47	22	78
a. Responsibility to make such decisions	field	39	61	25	75
	non-field	52	48	29	71
b. Assistance to evaluate practices	field	44	56	32	68
	non-field	48	52	21	79
c. Assistance to determine superior alternatives	field	55	45	31	69
	non-field	62	38	28	72
6. Acquiring and developing social and physical skills for agricultural leadership	field	62	38	61	39
	non-field	67	33	54	46

* Agronomic field workers—farmers, teachers and extension workers.
† Non-agronomic field workers—advanced studies, non-agricultural workers.

service, and (2) non-field workers; e.g., advanced studies, non-agricultural workers. Table V shows the rating by students in these two categories of the objectives. Again comparison is made between the two methods of instruction.

Such an analysis into agronomic field and non-field workers was made to determine which method of instruction was favored by any particular group of students (based on vocational preference). It has often been said that any approach other than the conventional subject matter approach would tend to be disliked by students interested in research or in vocations where application of principles to the solution of practical problems was limited. Table IV shows the break-down of students into vocation interests of (1) agronomic field workers and (2) non-field workers.

It can be seen from the table that the prospective non-field workers in the problem-solving recitations have rated their achievement significantly higher for all objectives (except 4) than the corresponding rating recorded by the lecture recitation students. In other words, non-field workers in the problem-solving recitations apparently considered they did relatively better in attaining these above-mentioned objectives than the non-field workers of the lecture recitations.

Student rating of this questionnaire, therefore, does not support the views sometimes held that problem-solving as a method of instruction is only of interest to prospective farmers and other agronomic field workers. In fact, on the contrary, non-field workers have indicated their preference for the problem-solving method even more than field workers.

For prospective field workers the same may be said for objectives 1, 2, 5, 5a, 5b, and 5c while objective 4 was rated about the same for both methods of instruction. Provision was also made on the question-

naire for students to indicate their own objectives for taking Agronomy I if they differed from those of the instructors. Almost all of those listed by students were included in one of the objectives stated by the instructors. The most common objectives stated were:

1. Relationship of soil to plants
2. Practical economy of lime or fertilizer applications
3. Soil conservation
4. To understand what soil scientists and farmer are talking about
5. To determine how agronomists may help undeveloped areas

Conclusions

Several conclusions from this study seem reasonable and justifiable in comparing problem-solving recitations with the lecture recitation method of teaching Agronomy I to this group of students.

1. This experiment supports the hypothesis that both prospective *agronomic field and non-field workers instructed by the problem-solving recitation method can solve agronomic problems more effectively* than those instructed by the lecture recitation method.
2. The lecture recitation and problem-solving recitation methods were virtually equal with respect to achievement on tests which required recall of specific information.
3. The problem-solving method has statistically significant advantages over the lecture demonstration method with respect to achievement on tests covering certain abilities in problem-solving.
4. Those objectives concerned with measuring student achievement in developing certain abilities in problem-solving were rated higher by students in problem-solving recitations than by students in lecture recitations.
5. A higher rating was recorded for most objectives by students in the promlem-solving recitations than by students in the lecture recitations, especially by the prospective non-field workers.

Recommendations

The findings from this study would indicate the following recommendations:

1. For greater achievement in problem-solving abilities in elementary soil science the procedures used as outlined in this study suggest ways in which learning situations and experiences may be improved.
2. The tests used in this investigation to measure problem-solving abilities could be further refined and then used more accurately to measure these outcomes.
3. The questionnaire used in this study revealed several weaknesses in making reliable comparisons between ratings; future study should be made of a more accurate system of student rating.
4. It is recommended that further investigation of this type be carried out and, particularly, more fundamental study be made in developing tests of more validity and reliability to measure problem-solving abilities.

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2. Barnard, J. Darrell. "The Lecture-Demonstration versus the Problem-Solving Method of Teaching a College-Science Course," *Science Education,* No. 3, Vol. 26, 1942.

3. Baar, Lincoln F. *Critical Selection and Evaluation of Enrichment Methods in Junior High School General Science,* New York Doctor's Dissertation, New York University, 1947.

BOOK REVIEWS

SMITH, ALSON J. *Immortality: The Scientific Evidence.* New York (70 Fifth Avenue): Prentice-Hall, Inc., 1954. 248 P. $3.00.

No question has been asked more often by human beings in every age than "What Happens to Me When I Die?" Is death the end of all? Sages, philosophers, scientists, ministers, even as you and I, have pondered the question. Christians have never had a doubt regarding life beyond the grave. Many persons have felt and believed that the human spirit survived death beyond the grave—even since the beginning of time. Theology has made such a belief the tenet of religious faith. Philosophically, such survival was logical.

The resurrection of Christ has been the center of the faith and belief of millions of Christians. These needed no further proof of immortality. But lacking has been scientific proof. All too often science has been materialistic and skeptical.

In this book, the author assembles all of the scientific evidence for life beyond the grave: the words of great scientists themselves, men like Compton, Millikan, Eddington, and Jeans; the evidence of psychic phenomena; the experiments of parapsychology. The evidence seems quite conclusive and impressive.

Altogether, this is probably the finest book along this line that has ever been written. It

should make believers of many skeptics and give firm assurance to all believers. This book should rank as one of the great books in religion in mid-Twentieth Century.

SOCKMAN, RALPH W. *The Whole Armor of God.* Nashville, Tennessee: Abingdon Press, 1955. 78 P. $1.00.

Seven brief devotional messages are based on Paul's inspiring words: "Therefore take the whole armor of God, that you may be able to withstand in the evil day, and having done all, to stand." Here Dr. Sockman shows how we today can put on the armor of God—how we can arm soul, mind, and spirit against all injury and destruction. There is a shield to protect you from the worst life can offer—from torturing doubt, from despair, from fear, even from death itself.

The seven chapters—vivid with illustrations, rich in inspiration—tell how we can acquire spiritual strength. The seven chapters are: The Whole Armor of God, The Girdle of Truth, The Breastplate of Righteousness, The Sandals of Peace, The Shield of Faith, The Helmet of Hope, and The Sword of the Spirit.

This is the last of nearly two score of very outstanding books by Dr. Sockman. Those who have heard him every Sunday for many years on National Radio Pulpit or have read one or more of his other books need no further recommendation as to the excellence of this book. Dr. Sockman is one of Americas best known ministers. He has served as Minister of Christ Church, New York City, since 1917.

PARROT, ANDRE. *The Flood and Noah's Ark.* New York (15 East 40th Street): Philosophical Library, Inc., 1955. 76 P. $2.75.

What does archaeological research say about *The Flood and Noah's Ark?* In this first volume of ***Studies in Biblical Archaeology,*** Parrot, distinguished French Archaeologist Curator-in-chief of the French Museums, Professor at the School of the Louvre and Director of the Mari Archaeological Expedition sets out, side by side, the Biblical and the Babylonian accounts of the Great Flood. Professor Parrot gives an account of the non-biblical stories, discusses their various sources. He tells of the archaeological investigations which resulted from the deciphering of the cuneiform writing on the ancient Babylonian tablets, and of the way in which the science of archaeology may help us to understand what we read in Genesis.

Researches in archaeology have not confirmed nor definitely disprove the Flood account in the Bible. Studies of geological deposits have been likewise neither confirmatory nor non-confirmatory. Reference is made to the failure of the Smith (retired North Carolina missionary) expedition to find Noah's Ark near the top of 16,945 feet high Mt. Ararat (The expedition will make an attempt in 1956 to again ascend Mt. Ararat.)

Students of archaeology and the Bible will both enjoy this account of research relating to the Flood and Noah's Ark.

PARROT, ANDRE. *The Tower of Babel.* New York (15 East 40th Street): Philosophical Library, Inc., 1955. 75 P. $2.75.

Genesis refers to the Tower of Babel. What is its true significance? What evidence for its existence does archaeology offer? In actuality none, for no remains have been found. However, similar high edifices, called ziggurats, have been found scattered over Mesopotamia.

Theologians by and large have long considered that the Tower of Babel was an expression of man's pride—a clenched fist raised in defiance towards Heaven. Professor Parrot rather believes it was rather meant as a hand stretched out in supplication, a cry to Heaven for help. In this book he presents his reasons for this belief. There are chapters on the archaeological evidence, the Tower of Babel in art, and the Tower of Babel and theology.

DE POL, JOHN. *The Sermon on the Mount.* New York: The World Publishing Company, 1955. 54 P. $2.00.

In the introduction Norman Vincent Peale says: "Without question the Sermon on the Mount is the greatest bit of writing in existence. Of all the millions of words produced, of all of the ideas ever expressed, these few pages are supreme in style and truth. This brief document has had and today exercises more creative influence for good than anything ever written or spoken. It is the source and inspiration of the basic philosophy of western civilization. . . ."

Following the introduction by Dr. Peale are the familiar words of the Sermon on the Mount. These are enhanced by eighteen wood engravings by John De Pol that form a sequence illustrating scenes from the life of Jesus. These engravings are unusually fine and add greatly to the attractiveness of this altogether most appealing little volume.

TAYLOR, G. AIKEN. *St. Luke's Life of Jesus.* New York (60 Fifth Avenue): The Macmillan Company, 1955. 161 P. $2.75.

The author in an unusual translation retells the story of the Gospel of St. Luke in modern, yet reverent language. Dr. Taylor has Luke writing and telling his story as if he were a reporter on a modern newspaper or writing an article for a magazine. The account adheres to the earlier translations and does not take liberties in deleting or adding to the account. Luke's original purpose in writing the Gospel is conveyed in this new version. Luke wrote to give the followers of the new religion the heritage of their faith, the foundation of their belief. Arranged as a continuous story without division into verse, the new translation provides absorbing and inspiring reading.

This is an excellent addition to biblical writing and makes Jesus, Luke, and their companions more alive and as if they were living now. Possibly the author will continue his outstanding con-

tribution by similar translations of other books of the Bible. A World War II veteran, Dr. Taylor has a Ph.D. degree from Duke University and is pastor of the First Presbyterian Church in Alexandria, Louisiana.

MONTAGU, M. F. ASHLEY. *The Direction of Human Development.* New York: Harper & Brothers, 1955. 404 P. $5.00.

This book discusses the biological and social bases that have and are now determining the direction of human development. *It offers a scientific confirmation of the enduring belief that human love is essential to all social growth.*

The author confronts the question: By what process does man become a social being? Drawing on an unprecedented assembly of research from biology, anthropology, and related fields, he has set forth the heavy weight of evidence to affirm the necessary role of cooperation and affection in the life of the individual in society. This is in essence a scientific validation of the eternal belief of poets and prophets in the importance of love in human affairs.

Valuable chapters bring together evidence of the decisive degree to which *the physiological growth and survival of the individual depend on the care and affection bestowed on the child during infancy.* Many case histories in animals and humans are cited.

Each chapter is a treat to read but the more interesting ones to the reviewer were: The Basic and Acquired Needs; Needs, Culture, and Values; Dependency, Interdependency, and Love; Love and the Privation of Love; Experience, Culture, and Personality; Isolation Versus Socialization; and The Direction of Human Development.

We want to quote the author's *Qualities and Characteristics of Love.*

1. Love implies the possession of a feeling of deep involvement in another, and to love another means to communicate that feeling of involvement to them. Love is not passive, it is active.

2. Love is unconditional, it makes no bargains and trades with no one for anything. It is given freely without any strings attached.

3. Love is supportive. It conveys to the loved one that he can depend upon those who love him, that they will always be standing by to give him the support he needs, with no questions asked, neither condemning nor condoning, but endeavoring sympathetically to understand that no trust will be misused, that no faith will be broken, that he will never under any circumstances be failed in his needs.

4. Love is firm. The firmness of love conveys to the loved one that both one's "yea" and one's "nay" are equally firm evidence of one's love.

5. Love is most needed by the human organism from the moment of birth. Love is the birthright of every human being.

6. Love is reciprocal in its effects and is as beneficial to the giver as to the recipient. To love another means to love oneself as well as the other.

7. Love is creative in that it actively participates in the creative development of the loved one as well as contributing to the further development of the lover.

8. Love enlarges the capacity of those who are loved and of those who love so that they become increasingly more sensitive in probably all areas of their being.

9. Love continually elicits, by encouragement, the nascent qualities of the loved one. In the absence of love, these capacities will either fail altogether to be elicited or fail of healthy development. The person who has been loved is more efficient than the person who has been inadequately loved.

10. Love is tender, with a tenderness that abjures every form of insensitivity and every form of violence.

11. Love is joyful, it is pleasure giving, happiness-producing, it is goodness itself.

12. Love is fearless. Love has no element of fear in it, and produces no fear in others. Love tends to reduce fear, allay suspicion, soften all harshness, and produce peacefulness.

13. Love enables a person to treat life as an art which the person, as an artist, is continually seeking to improve and beautify in all of its aspects.

14. Love is an attitude of mind and as a form of behavior is adaptively the best and most efficient of all adjustive processes in enabling the human being to adapt himself to his environment.

15. For the person and for the species love is the form of behavior having the highest survival value.

Adequate love is necessary for adequate physical growth and development of the human organism as well as for its psychical growth and development; and intelligence as well as mental health is furthered by the contribution which love makes to the developing person.

Thus the author sees love as the essential touchstone of every aspect of human development.

Practically applied, the essence of the book could revolutionize human society. Most of the ills of our society could almost be wiped out—juvenile delinquency, problems of discipline, divorce, broken homes, crime, gambling, drinking, racial hatreds, biases and prejudices, war threats and tensions, even war itself—by real love properly developed at the appropriate time. It would mean women remaining at home during the period when children are so in need of love. Maybe that is the only real, permanent solution to many of our personal and social problems. Possibly present-day gains—financial and otherwise of women in employment who are mothers—is more than counter-balanced by the problems and present ills of society in terms of financial and other costs.

This book could readily be the most significant book of this era. It is a truly challenging one.

Many readers will recall the author's earlier books *On Being Human, On Being Intelligent, Man's Most Dangerous Myth: The Fallacy of Race,* and *The Natural Superiority of Women.*

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